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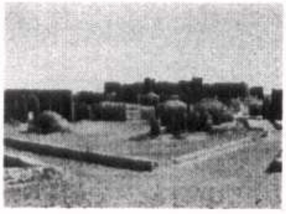
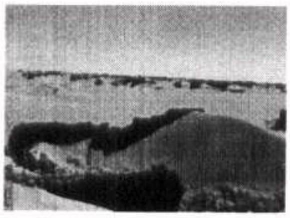
MINIMIZING OF THE NATURAL HAZARDS ON SOME MONUMENTAL SITES IN EL GIZA PYRAMIDS PLATEAU AND EL KHARGA OASIS, WESTERN DESERT, EGYPT, BY STUDYING THE GEOLOGICAL PHENOMENA





EGYPTIAN GEOLOGICAL CONSULTING OFFICE (EGCO)

(DR. ABDEL ATY SALMAN)

Presented to: Egyptian national committee for Culture & Science & Education (UNESCO)

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CONTENTS

PREFACE

The numerous monuments in various places of Egypt witnessed its seven thousand years of civilization. Many cilvilization, passed during this long period of time like the Pharaonic, Roman,Greece,Coptic and Islamic.

These monuments are of utmost value from both the historical and economic point of view as the Egyptian economy relies to a large extent on the income of tourism.

The Egyptian National Commission for UNESCO always adopts projects that deal with conservation of the natural and cultural heritages, at the same time it encourages NGOs. Egyptian National Commission submitted to UNESCO proposal on a project entitled "Minimizing of the natural hazards on some monumental sites in El Giza Pyramids Plateau and El Kharga Oasis, Westren Desert, Egypt, by studying the geological phenomena "prepared by the Egyptian Geological Consulting Office (EGCO) a non-governmental organization in Egypt. UNESCO approved this project.

The project includes a study where the authors tried to shed light on the hazards affecting the invaluable monumental sites whether they are natural or man-induced. They used the space images in constructing geological maps illustrating the different geological phenomena that affect the great pyramids and the Sphinx beside some other important archaeological sites in Kharga Oasis the Western Desert of Egypt like the temples of Hibis, Nadura,Bagwat, El Ghueita and Zayyan.

In Giza plateau, it was concluded that the main hazards are controlled by faults, fractures and ground water effect, beside the karstification phenomenon. Moreover, the weathering factors and man-made actions represent additional deterioration factors. The deterioration of the Kharga Oasis temples are due to ground water, the moving sand dunes and the biological action of birds and other minute organisms, beside the man-made hazards.

The project states the results of investigations and suggests recommendations to minimize these hazards.

ACKNOWLEDGEMENT

*THE EGYPTIAN GEOLOGICAL CONSULTING OFFICE (**EGCO**) PRESENTS HIS GRATITUDE TO **UNESCO** MEMBERS IN EGYPT OFFICE FOR THEIR COMPLETE COOPERATION DURING THE PERFORMANCE OF THIS STUDY. SPECIAL THANKS ARE DUE TO ENG. SAFWAT SALEM, MRS. MONA ALLAM, MRS. GAZEBIAH ABD EL RHMAN AND THEIR COLLEAGUES FOR THEIR EXCELLENT MANAGEMENT.*

***EGCO** LIKES TO PRESENT LOT OF THANKS TO THE MAIN CONTRIBUTORS SCIENTISTS WHO ARE PARTICIPATED IN THE PERFORMANCE OF THIS STUDY. SPECIAL THANKS TO DR. ASHRAF M. WALLY (PROFESSOR OF GEOLOGY, GEOLOGY DEPARTMENT, FACULTY OF SCIENCE, CAIRO UNIVERSITY), DR. M. EL SANKARY (ASSOCIATE PROF. IN GEOLOGY, NMA, CAIRO, EGYPT), DR A. ZEIN (ASSOCIATE PROF. IN REMOTE SENSING AND GIS, NMA, CAIRO, EGYPT) AND DR. MOHSEN M. SALEH (LECTURER IN MONUMENTS RESTORATION, THE FACULTY OF ANTIQUES, CAIRO UNIVERSITY).*

ABDELATY B. SALMAN
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Abstract

The present work deals with the study of the geological phenomena to be applied in minimizing the natural hazards on some monumental sites in El Giza Pyramids Plateau and El Kharga Oasis, Western Desert, Egypt. The space images are interpreted and analyzed to define the main geological features for constructing photogeologic maps. During field study these maps were checked and geologic maps were constructed and most of the promising geological phenomena were documented.

In El Giza Pyramids Plateau it is found during this study that the main hazards are controlled by: Rocks and foundation bed instability due to the presence of weak zones as a result of faulting and fracturing effects. Some of these faults could be of capable type. Moreover, the presence of karstification phenomenon and caving due to the combined effect of the geologic structural pattern, type of sedimentary rock units, ground water circulation, rains, humidity and surrounding environmental polluting agents are forming another hazards. The weathering, erosion factors and man made actions represent additional deterioration factors on the monumental complex in this important site.

According to the above detected hazards, the following points are recommended for El Pyramids Plateau Monumental Complex:

**Accurate fixing, treatment and supporting works for the easy slide blocks in the small escarpments nearby Khafre, Mankare pyramids. The zone of the NW-SE trending fractures which dissecting the foundation bed rock at the north eastern part of Khufu Pyramid should be also treated.*

**An application of suitable geophysical studies to explore the attitudes of the major faults, especially those bearing a northwest trend and caves in El Giza Pyramids monumental complex. This is rather important to find out the*

best solution to restore and strengthen the weak zones and to overcome any serious hazard in the future.

**Recent tectonics study is of prime importance and is strongly recommended. This study is used to determine the association of earthquakes with seismically active structures which can bear a real hazard on some parts of the monumental complex site in El Giza Pyramids Plateau. This study should include investigation about surface faulting potential to identify capable faults. If the presence of capable faults is proved, it is necessary to study their chronology. The dating of these faults can be determined by a number of techniques such as structural superposition, stratigraphic superposition and geomorphologic and isotopic dating methods.*

**It is important to mention that the Great Sphinx is associated with marly limestone and marl which are soft and characterized by numerous fractures intersection. Moreover, the Sphinx its self is suffering from fractures influence. In addition to other deterioration factors, fractures form a real hazard on the Sphinx. If there is any possibility for earthquakes hazard, even with small magnitude, it can dramatically affect this important monument. So, from this point the importance of determination of any nearby capable faults and their relation with earthquakes is very essential.*

**The ground water situation in the Great Sphinx zone should be watched and must be kept in a suitable and safe level. This is rather important, because the under ground water can form a real hazard on the Sphinx site. This is because the Sphinx is located at a lower level at the eastern slope of El Giza Pyramids Plateau and can be subjected to a great hazard due to ground water seepage.*

Based on the present study of the geological phenomena in El Kharga Oasis monumental sites, it is found that the most remarkable hazards are summarized in the following main factors:

***Ground water** and rains; the ground water effect is rather clear in the site of Hibis Temple due to its presence in a relatively low geographic level in El Kharga Oasis Depression. The source of the ground is mainly from the irrigation water used for the dense cultivated nearby areas. The rains are scarce in this area, however, they form a real hazard on the monuments contains mud brick structures like El Bagwat, El Ghueita and Qasr Zayyan sites.*

***Sand dunes** form a real hazard on most of the monumental sites. It is found that these dunes are moving fast and partly accumulate nearby some monumental sites and completely destroy some relatively recent villages and some cultivated lands. Moreover, these dunes represent a near source for sandy winds storms which make wind erosions are very effective in these sites.*

*Another important hazard factor is the **biological action** of birds and other minute organisms. Moreover, the man made deterioration factor is not uncommon.*

According to the above detected hazards, the following points are recommended for El Kharga monumental sites:

**The ground water situation in the site of HIbis Temple should be watched and must be kept in a suitable and safe level. This is rather important, because the under ground water can form a real hazard on the foundation bed of this temple. The water source should be blocked by constructing some isolating barriers on the bases of correct study for the under ground water and seepage conditions. De-watering of the soil under the temple is recommended, but this should be based on scientific bases to prevent any collapse in the foundation bed. Grouting can be recommended. But the zone to be grouted, the type of grout to be choose, and the likely extent of the grout penetration under a given pressure. Also the nature of soil and the practical experiences can demonstrate the spacing of grout holes in different soil types.*

**Performing a detailed study for sand dunes around all monumental sites in El Kharga Oasis. This study should include the wind dynamics, rates of dunes movements in each direction, the factors controlling dune movements and their accumulations in such arid environment.*

**Applying all possible techniques to reduce the biological action on all the monumental sites. That is because the biologic effect is very dangerous especially on the reliefs (drawings) of the archeological sites.*

At the end of this study a Plan for conservation and restoration of some archaeological sites in El Giza Pyramids Plateau and El- Kharga Oasis are included. This plan is very useful and can be easy applied and it also represents an educational approach for this important field.

REMARK:

Fig.5* the coloured figures in the text are citted in the appendix. They have sign* after the figures number.

MINIMIZING OF THE NATURAL HAZARDS ON SOME MONUMENTAL SITES IN EL GIZA PYRAMIDS PLATEAU AND EL KHARGA OASIS, WESTERN DESERT, EGYPT, BY STUDYING THE GEOLOGICAL PHENOMENA (18322409 EGY)

General Introduction

The Egyptian Geological Consulting Office (EGCO) which represents NGO, Egypt, presented a proposal for UNESCO participation program of 2002-2003. That proposal included two items: The first one entitled: Minimizing of the natural hazards on Giza Pyramids and associated monuments by studying the geological phenomena of the Pyramids Plateau, Giza, Arab Republic of Egypt. The second one entitled: Minimizing of the natural hazards on the monumental sites by studying the geological phenomenon especially sand dunes in Kharga Oases, Western Desert, Arab Republic of Egypt.

On the beginning of year 2005, EGCO was informed through Cairo's UNESCO Office that the proposal has been accepted by main UNESCO Office but the two projects have been gathered in one project including both Pyramids Plateau and El Kharga Oasis as indicated from its above title.

DuringJan. and Feb.2005, rules for the performance of the project have been discussed between Cairo's UNESCO Office and EGCO and all things were settled. The performing program has been proposed for completing the project (Table 1).

According to this table, the total performance time recommended will be six months starting from March 1, 2005 to August 31, 2005. However, this time table could be subjected to some changes depending on unexpected events or upper hands governmental decision makers.

According to this table, the total performance time recommended will be six months starting from March 1, 2005 to August 31, 2005. However, this time table could be subjected to some changes depending on unexpected events or upper hands governmental decision makers.

It is important to mention that the High Committee of the Egyptian Antiques Authority has agreed on the performance of this project at 14 of September, 2005. EGCO has received their approval at 18 September, 2005.

Table 1: Proposed time table for performing the study

Stages Month	**Description**	Time in month (2005)					
		3	4	5	6	7	8
I	**Preparation stage:** Includes obtaining the necessary permissions and official letters, a survey on the previous related works, obtaining the Satellite images and/or aerial photo-graphs and topographic maps which cover the study area. Through this stage a photo geological maps will also be prepared on the basis of the analysis of Satellite images and / or aerial photographs.	xxxxx					
II	**Field investigations:** This stage includes field studies as: defining the geological units and the associated features, measuring litho-stratingaraphic sections and sketches, geologic structures, weathering and alterations units and collecting representative samples			xxxxx			
III	**Laboratory works:** This stage represents, petrography and geochemical studies for some collected samples					x	
IV	**Report:** Data treatments and interpretation, preparation of the final geologic maps and producing the final report.					xxxx	

This study is based on utilization of the colour composite satellite images for preparation of preliminary photogeologic maps as base maps which have been modified to geologic maps after the performance of the field studies and laboratory investigations for the studied areas.

For the **Giza Pyramids Plateau** a colour composite satellite image is prepared (Fig. P4). This image is treated and analyzed for construction of a preliminary geologic map for Pyramids Plateau area. Moreover, a structural lineament map has been constructed. These preliminary maps have been included in the report of stage I of the project.

With respect to **El Kharga Oases area** it is divided into two parts (Figs. K2 and K3). The northern part includes El Kharga City and the main monument sites as Hibis, El Nadura Temples and El Bagwat cemetery. A Landsat image has been treated, analyzed and interpreted to construct a preliminary geologic map the available topographic maps and previous geologic works have been utilized to construct this map.

The second part (central) of El Kharga Oases includes Qasr El Ghaueita Temple and Qasr Zayyan as monumental sites. A Landsat image (Fig. K4) has been treated, analyzed and interpreted to construct a preliminary geologic map. The available topographic maps and previous geologic works have been utilized to construct this map. These maps are presented in the stage I of this project.

Moreover, these images have been used as base maps for collecting the field observations and define the interesting geologic features which have relations with the subject of this study. The collected field observations and studies are used in the preparation of geologic maps for some chosen monumental sites in both El Giza pyramids plateau and El Kharga Oasis. The studied geologic features, the other field observations and laboratory studies are used to define the natural hazards on the monumental sites and proposing the suitable recommendations for minimizing these hazards and a restoration plan for the studied monumental sites in El Giza Pyramids Plateau and E Kharga Oasis.

PART I: EL GIZA PYRAMIDS PLATEAU

I.1. Introduction

"From a top these pyramids, forty centuries look down upon you."
-- Napoleon Bonaparte to his soldiers before the Battle of Giza, 1798

When Khufu, perhaps better known by his Greek name, Cheops, became king of Egypt after the death of Sneferu, there was no convenient space remaining at Dahshur, where Sneferu was buried, for Khufu's own pyramid complex. Hence, he moved his court and residence farther north, where his

Prospectors had located a commanding rock cliff, overlooking present day Giza, appropriate for a towering pyramid (Fig.P1). This rock cliff was in the northernmost part of the first Lower Egyptian name, Ineb-hedj ("the white fortress").

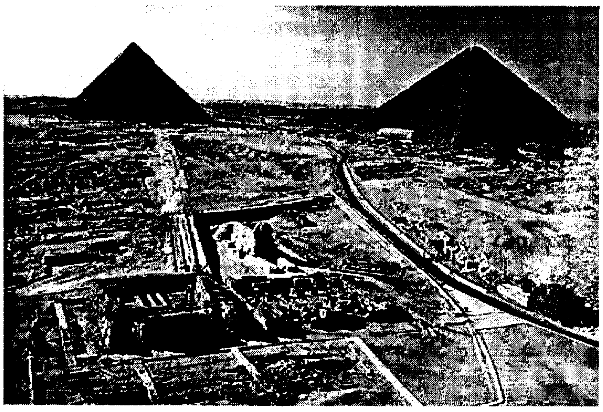


Fig. P1: Image map for Giza pyramids Plateau

Giza is located only a few kilometers south of Cairo, several hundred meters from the last houses in the southernmost part of the city proper, where a limestone cliff rises abruptly from the other side of a sandy desert plateau. The ancient Egyptians called this place imentet, "The West" or kher neter, "the necropolis". The main components of the Giza Pyramids Plateau are obvious in Fig.P 2.

According to a treatise on the geology of the pyramid plateau by Thomas Aigner, it is part of the Middle Eocene Mokattam Formation, which dips slightly southeast, comprising limestone and dolomites. To the south, the Mokattam and dolomitic limestones are overlain by the marly limestone and sandy marls of the Upper Eocene Maadi Formation. To the north and east, the

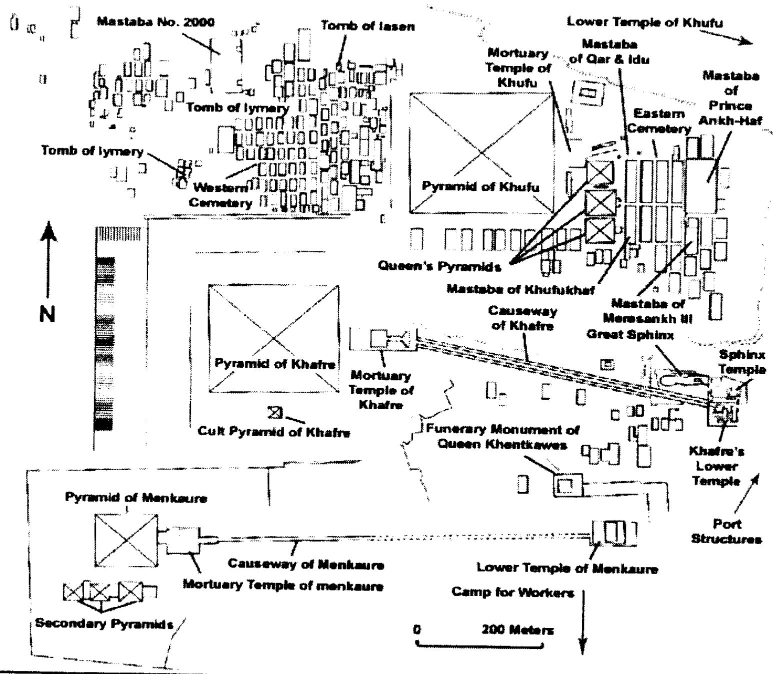


Fig.P2: Image map for Giza pyramids Plateau

Mokattam Formation is characterized by two steep escarpments about 30 meters (92 feet) high. It continues to the Great Sphinx ditch, which must at one time have formed a high peak. From there, the stonemasons cut the core blocks for the Great Pyramid (http://www.touregypt.net/featurestories/pyramids.htm).

Fig.P3 shows a general geologic cross section for the foundation geologic formations in El Giza Pyramids Plateau. The older pyramids of the third and early fourth dynasty were built on thick layers of marl and slate. These marl layers were easier to dig than limestone, so excavation of the large shafts that extended as much as 30 meters beneath the step pyramids was accomplished in a reasonable time. However, there was also a serious disadvantage, because the marl layers could not support their weight. The underlayer gave way, and the construction became unstable. This in fact happened with the South Pyramid at Dahshur, where cracks and serious damage appeared in the corridor system and in the chambers so that the pyramid had to be abandoned.

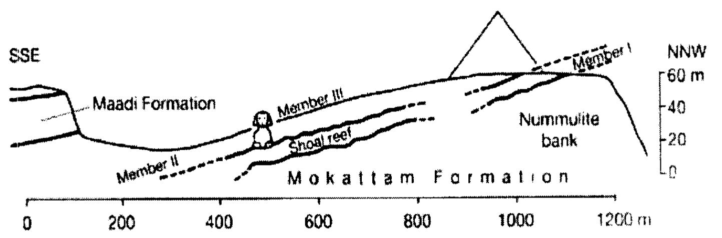


Fig.P 3: Side View of Giza Pyramids Plateau (Section)

Hence, when Khufu planned his own ambitious pyramid, he was looking for a solid rock base, nearby quarries and a dominating position overlooking the Nile Valley, which he, of course, found at Giza.

Giza can be subdivided into two groupings of monuments, clearly defined and separated by a wadi. The larger grouping consists of the three "Great" pyramids of Khufu, Khephren [Khafre], and

Menkaure, the Sphinx, attendant Temples and outbuildings, and the private mastabas of the nobility.

The second grouping, located on the ridge to the southeast, contains a number of private tombs of citizens of various classes. While the majority of the monuments of the larger grouping are made from limestone that was quarried and transported to the site, the tombs of the smaller grouping are simply carved out of the native rock.

Though the three Great pyramids are the most famous and prominent monuments at Giza, the site has actually been a Necropolis almost since the beginning of Pharaonic Egypt. A tomb just on the outskirts of the Giza site dates from the reign of the First Dynasty Pharaoh Wadj [Djet], and jar sealing discovered in a tomb in the southern part of Giza mention the Second Dynasty Pharaoh Ninetjer. But it was the Fourth Dynasty Pharaoh Khufu [Cheops] who placed Giza forever at the heart of funerary devotion, a city of the dead that dwarfed the cities of the living nearby. In order to build his complex, he had to clear away many of the old tombs, filling in their shafts or even totally destroying them. His pyramid, the largest of all the pyramids in Egypt (though it should be noted that it surpasses the Red Pyramid at Dahshur built by his father Snefru by only ten meters), dominates the sandy plain.

On its southwest diagonal is the pyramid of his son, Khephren(Chephren, Khafre). Although it is smaller, a steeper angle results in the illusion that they are the same size. In fact, Kephren's pyramid appears taller since it is on higher ground. The notion that this was done on purpose to out-do his father is without question. As it occupies the central point, has the illusion of greater size, and still has some of its casing stones intact, it is frequently mistaken to as the Great Pyramid. Further along the southwest diagonal is the smallest of the three great pyramids, that of Khephren's son Menkaure. It is also the most unusual. First of all, it is not entirely limestone. The uppermost portions are brick, much like the several Pyramids at Dahshur, though separated from them by several centuries. One theory is that Menkaure died before his pyramid have been

completed, and the remaining construction was hastily done to finish it in time for the burial. It is also not along the diagonal line that runs through the Great Pyramid and the second Pyramid, but instead is nearly a hundred meters to the southeast. This error, if error it is, is of a magnitude not in keeping with the mathematical skill known to have been possessed by the ancient Egyptians. However, an idea has emerged in the last few years that the three large pyramids of Giza are actually meant to be in an alignment resembling that of the three "belt" stars in the constellation Orion: Alnitak, Alnilam, and Mintaka. This theory is largely discounted by the majority of Egyptologists, but some do believe it is a point to ponder. Actually, it should also be noted that, while the center of the pyramid does not line up with its larger counterparts, the southeast sides of all three pyramids are in alignment.

All three pyramids stand empty, probably plundered during the political unrest that ended the Old Kingdom when the monarchy collapsed. Yet there are the occasional surprises. Airtight pits along the southern and eastern walls of Khufu's pyramid contain boats (not small ritual boats, but fully-functional funerary barges with 40-ton displacements. One was excavated in 1954).

Exactly how big Giza is may never be known. Excavations have continued to find new tombs and artifacts since Bezoni, Caviglia, Perring, and Vyse began the first systematic study of Giza in the early 1800s. It has been explored and excavated more thoroughly than any other site in Egypt, possibly more than any other site in the world, yet no one believes the research is anywhere near complete today.

Throughout the Old Kingdom, the cemetery of Giza remained the most prominent, even when the kings moved again to Southern Saqqara. For example, important officials such as the architects of the 'inti family, who constructed the pyramids of the 5th and 6th Dynasties, they continued to live in the pyramid town of Khufu and had their family tombs at Giza.

During the first Intermediate period, the pyramid town of Khufu and the cemetery of Giza were both abandoned, and they remained so during the Middle Kingdom In fact, the pyramids were forcefully

opened and plundered, and the private tombs were not ignored by thieves either. The causeways and Temples were in fact even used as quarries by the architects of the kings of the12th Dynasty (http://www.touregypt.net/featurestories/pyramids.htm).

This all changed completely during the new Kingdom. The kings of the 18^{th} Dynasty showed deep respect for the pyramids as monuments of their ancestors at Giza, and the area gained considerable religious significance as the center of royal worship to the Great Sphinx, "Lord of Setpet, the" Princes and kings of the 18th and 19^{th} Dynasties erected stelae between the paws of the Sphinx, which was no longer seen as a royal statue but rather as an image of the sun god Harmachis, "Horus in his Western Horizon", which was actually a reference to the "Horizon of Khufu". Amenhotep II dedicated a small Temple to Harcachis to the northeast of the Sphinx. On foundation tables of that Temple, the Sphinx is also named Harmachis-Hauron. Hauron was the name of a Syrian-Palestinian god of the netherworld that a community of Syrian-Palestinians living near the Great Sphinx identified with his image. Ramesses II installed a sanctuary within the forepaws of the Sphinx.

In the late period, Osiris became the dominant god of the area, taking over the cult locations of Rostau from Sokar and installing his cult in the Sphinx. High, massive pedestals were actually added to the body of the Sphinx, on which chapels of Osiris and probably Isis stood. Isis became known as the "Lady of the Pyramids."

During the Sixth Century BC onward, Greek travelers admired the pyramids at Giza, and it was they who eventually placed the monuments in the list of the Seven Wonders of the Ancient World.

After the Pharaonic Period, and up until recently, stone from the monuments were taken and used to build buildings in nearby Cairo. First the polished white limestone "casing" was taken, then the softer core stones. Many of Cairo's oldest buildings are built partly from stones from the pyramids. This destruction continued well into the Nineteenth Century until preservation efforts and a resurgence of national pride put a stop to it. It is believed that had the pyramids not been vandalized, they would still remain to this day much as they

were when they were built. As the saying goes, "Man fears Time, but Time fears the Pyramids." The pyramids plateau hosts more than known 90 pyramids and within its premises the main three pyramids were constructed. This region has an extension from Giza till Fayoum governorate. The famous Cheops Pyramid (IV Dynasty); Chephrea pyramid (IV Dynasty), Mykerinos, Sphinx and Khentkaus (Beginning of V Dynasty) with some mastabas and tombs are the main archeological sites.

The Giza Plateau is one of the most important archaeological sites hosts more than known 90 pyramids and within its premises the main three pyramids were constructed. This region has an extension from Giza till Fayoum governorate. The famous Cheops Pyramid (IV Dynasty); Chephrea pyramid (IV Dynasty), Mykerinos, Sphinx and Khentkaus (Beginning of V Dynasty) with some mastabas and tombs are the main archeological sites.

A composite satellite image (Fig.P4) has been prepared; it shows the sites of the three main Giza pyramids with the surrounding environmental elements.

I.2. Geologic Setting

The carbonate rocks represent almost 1/3 of Egyptian geologic column, particularly starting from Late Cretaceous, Paleocene and Eocene ages. The exposed oldest rocks in Cairo region are the classic upper and middle Eocene section of G. El Mokattam (Said, 1962; 1990, Sweedan, 1991 and Dowidar and Abd-Allah, 2001). This extension formulates the famous chalky plateau excavated by the River Nile lying down its Neonile fine sediments. Minor fractures, faults, gypsum filled fractures, local dolomitization and ferruginated bands were recorded with solution cavities representing the main features in the plateau (Soliman, 1996). It is noteworthy to mention that Soliman has several valuable studies on the monumental sites in Giza Pyramids Plateau (Soliman, 1998, 1999 and 2000). The Eocene Mokattam Formation section was subdivided by Hume (1911) into Upper, Middle and Lower Mokattamian members at the pyramids. Plateau. The Upper member (*Carolia Placunoides beds*). Middle member (*Nummulites striatus* and *Exogyra beds*) and (*Nummulites gizehensis beds).*

The age of the Mokattam Formation was considered to belong to the M. Eocene age (Sweedan, 1991), whereas Strugo (1985) referred it to lower to Middle Eocene age. The lithologic descriptions of the detailed measured sections are referred to Dowidar and Abd-Allah (2001), where two lithostratigraphic logs were tentatively measured and described. The first section is located Qibli El Ahram hill and the second at Darb El Fayoum. The harder nummuilitic limestone and dolomitic limestone are exposed in the northern part of the plateau, while the softer nummuilitic limestones occupies the central part and the argillaceous limestone with alternating marls and shales are exposed at the southwestern part of the plateau. The paleotopographic configuration of the pre-Eocene plays a controlling parameter on the distribution, thickening and thinning out of carbonate sections. The lithofacies distribution is almost the same due to the consistent stability of the Eocene marine environment starting since Cretaceous age. Distinguishably, the Late Cretaceous carbonate rocks (Khoman Formation); Early to Middle Eocene (Minia and Naqb Formations) and the Upper Eocene (Mokattam Formation) are mainly of carbonate and clastic composition, while southwards Drunka, Dungul and Naqb Formations are more siliceous and cherty in composition (Hermina et. al., 1989). The exposed Middle Miocene carbonates cover the northern part of the Western Desert is known as Marmarica Formation.

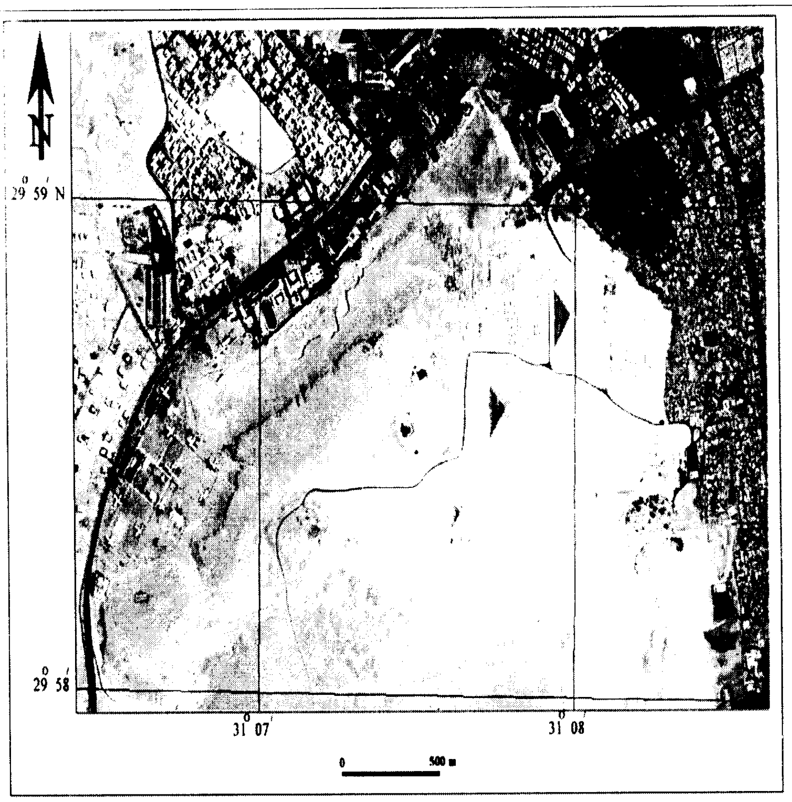


Fig.P4: Colour composite satellite image of Giza pyramids plateau showing the various environmental elements

Topographic level of the monumental pyramids did explain one major item concerning the choice of the plateau as constructing sites for the monumental sites started since Pharaonic and lasts till Roman ages. These carbonate rocks represent mainly the plateaus in the Western Desert, where most of monumental sites were constructed either on or at the carbonate rocks. Definitely, the plateau sculpturing was prior to civilization citing and/or choice of the selected areas. This might be attributed to older beliefs concerning being at higher and safer altitudes or closer to the "Atone, the god of the sun". All

these beliefs and many others, still unknown, are the parameters that led the old Egyptian to choose the plateaus as the choice for eternity.

From geographical point of view, attempts defining and categorizing the origin of the sculptured units reflecting the affecting parameters and their effects on the different rock types was the challenge of many authors starting by the old Pharaonic engineering staff to which responsibilities for building site choices were devoted. The detected bases as deduced from old papyrus indicate with no doubts that knowledge was expanding concerning the awareness of geology and morphologies. The oldest mining gold map is a decisive, supportive and documentary proof towards understanding geologic and geomorphic sciences, even if approaches are of different aspects.

Embabi, 2004 presented an excellent detailed analog on the geomorpho-logy of the Western Desert including the controlling factors that led to the present-day configuration. Particular interest to the effects of humidity and water representing as the dynamic print with time was paid to the different rock types and the carbonates with special emphasis. Caving and karstification are two common phenomena used by the different civilizations in many aspects, burying of tombs, monuments, mining routes and even as a shelter during beginning of Christianity.

Till 2004 a total of 14 caves were discovered in the western Desert, 6 of them at the Pyramids area, Giza Governorate (Embabi, 2004) as indicator of exploitation activities with beliefs of usage. Most if not all were located within the carbonate rocks as a naturally affecting host by water and humidity as factors responsible for caving with its demonstrative stalactite and stalagmite carrot-shaped forms. At the Giza pyramids activities of exploring the caves and karst forms are referred to El-Aref and Refai (1987) whom definition of several karst forms were defined. It is known that there are three large caves are present which are nominated; Nazlat El-Seman, the Sphinx and Kinikaus caves.

The Eocene limestone of the pyramids Plateau is characterized by landforms of stepped terraced escarpment and karts ridges with

isolated hills. The carbonate country rocks are also dominated by minor surface, surface to subsurface and subsurface solution features associated with karsts products. The lithologic and structural characters of the limestone country rocks comprise the main factor controlling the surface and subsurface karsts evolution. The development of the karsts features and the associated sediments in the study area provides information on the paleohydrolic, chemical and climatic environments involved in the origin of karstification. (El Aref and Refai, 1998).

The Eocene carbonate rocks forming the bulk of the Giza Pyramids Plateau are highly fractured by west-northwest, northwest and northeast trending fractures.

The fractures in the Eocene rocks play the main role in karst formation and rock instability of the Pyramids Plateau. Karst cavities exist in for forms surface, pocket, bedding plane and fracture cavities. Bedrock settlement is diagnosed as falling of the roof beds in the karst cavities. Injections by shotcrete and use of rock bolts are recommended for supporting the foundation beds and stopping the settlements (Dowidar and Abde-Allah, 2001).

Abdel-Samei, 1997, studied the treatment and conservation of the Royal Tombs in the Old Kingdom period at Giza Plateau, with practical work on one of the selected tombs. In this study he measured the attitude of the faults and fractures at the sites of the pyramids and some associates monuments. He described these structural features, tabulated them and discussed their effect on the monuments. Abdel Khalek, et al., 1989 studied the structural history of Abu-Roash district which is located to the west of El Giza Pyramids Plateau. The Syrian Arch structure is well represented in this district where its echo is extended to El Giza Pyramids Plateau

This Ancient Egyptian Calendar (An. Eg. C.) has been the basis of virtually all known later calendars with changes and/or notifications of the beginning, names, divisions... We Egyptians have forgotten and the other's seem to ignore or to be oblivious of the Egyptian source...According to the An. Eg. C., the year 1996 AD

would be 6236 Eg.C. (4240+1996) and the approaching 21st Century AD will be in the 64th Century Eg. C...

Time wise, the Great Pyramid of Khufu (1702-1724 Eg.C. or 2538-2516 B.C.) according to Emery's calculations (1960 AD or 6200 Eg.C.) will survive thousands of years to come under the present weathering conditions. From talus as tiers and at pyrarmid base, he estimated a rate (since ab. 1000 years) of 0.2mm/year erosion over the whole Pyramid surfaces that are 0.01% of total volume.

Such erosive effect on Egyptian monuments has been the resultant of sedimentary factors. The surface agents and processes deal with the nature of wind, water, dew, organisms, temperature... while others deal with the monument architectonics, materials used, ... together with the time interval of exposure to these agents (Soliman, 1997).

The carbonate rocks of the Sphinx were structurally, chemically and mineralogically studied. The investigated rocks (Upper and Middle Eocene age) suffer from both chemical and mechanical weathering. Human pollution in addition to natural forces (wind, rain, dew, and temperature) has their environmental impact on the rocks. Field observation revealed the presence of fractures in the form of laminations and fractures in addition to iron stained patches and thin sheets of salts in some parts of the Sphinx, which can be related to the rock composition and to some external factors.

The upper layers of the Sphinx are of marly and micritic limestones which suffer rapid alteration and decomposition. The lower layers are dominated by dolomitic and sparry limestone which is more compact and weather resistant. The chemical analysis of representative samples reveals that some compounds such as SiO_2, Fe_2O_3, MnO, P_2O_5, Al_2O_3, MgO, CaO, Na_2O, K_2O, SO_3, Cl, L.O.I. and I.R. are variable in concentration depending on the composition of rock samples and location of the sampled horizons. Therefore, the Sphinx rocks show complex problems as: Contamination with halite, ground water percolation, fracturing, cracks, and chemical weathering in addition to the climatic factors which produce continuous fractured

zones and foliated layers on the surface of the statue (Barakat et al., 1997). Barakat, et al., 1974 made electromagnetic experiments at the pyramids of Giza.

I-3.Site Geology of El Giza Pyramids Plateau

I-3.1. Stratigraphy

During the present study, a composite space imagery (Fig.P4) has been interpreted. A geologic map (Fig.P5*) has been constructed based on this interpretation, field work and some previous works (Dowidar and Abdallah,2001). Moreover, two geologic cross sections have constructed to define the stratigraphic relations between the various lithstratigraphic units and the prevailing structural features especially faults and bedding (Figs. P6* and P7*).

The exposed Middle Eocene rocks were subdivided from base to top into the Mokattam, Observatory, Qurn and Wadi Garawi Formations; whereas the Upper Eocene rocks are represented by the Wadi Hof Formation (Figs.P5*, P6* and P7*). Post-Eocene sands and gravels unconformably cover the Eocene bedrocks in several parts of the study area. These deposits fill some fractures, holes and depressions on the upper surface of the plateau. In parts, they are highly ferruginous, forming several clastic dykes and pockets.

The outcrops of the Eocene rock units are controlled mainly by the gentle (~ 5°), south to southeastward general dip of the plateau rocks. So, the Qurn, Wadi Garawi and Wadi Hof Formations are exposed in the southern part of the plateau, whereas the Mokattam Formation is exposed in the northern part of the plateau forming very steep scarps. The Mokattam Formation consists of three members. The lower and middle members are exposed in the northern and northeastern parts of the plateau and composed of hard nummulitic and dolomitic limestones. The upper member is exposed in the central part of the plateau and composed of softer nummulitic limestones. The Observatory Formation occupies the middle part of the plateau and composed of argillaceous limestones and marls, upon which the second and third pyramids and the Sphinx were constructed. On the other hand, the marls, shales and sandy limestones of the Qurn, Wadi Garawi and Wadi Hof Formations are down-faulted against the

Observatory Formation in the southern parts of the plateau. The Wadi Hof Formation is capped by highly fossiliferous sandy and dolomitic limestone beds. These southern plateau rock units are measured for the present study in exposed section at the south of the third (Menkaure) pyramid by about 250m (Fig.PL1, PL2 and P8). Various lithologic sedimentary exposures are exposed around pyramids (Figs: PL3 to PL8).

Fig.P L1: Top of the hill of the measured section, El Giza Pyramids Plateau

Fig.P L2: Hard fossiliferous lime stone bed in the measured section

Fig.PL3: Lithostratigraphic units of shales, marl and limestone beds, south east of Sphinx

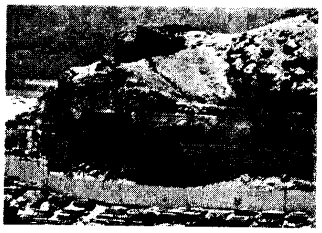


Fig.PL4: Close up view for the rock units of Fig.PL3, showing tilting in the upper unit, south east of Sphinx

Fig.PL5: Limestone-marl intercalation, southern part of El- Giza plateau Pyramids Plateau

Fig.PL6: South east trending contact zone between urban areas and El Giza Pyramids Plateau

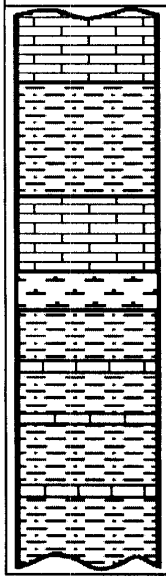
Lithologic log	**Thickness (m)**	**DESCRIPTION**
	Top	Fossiliferous, blackish, fractured, very hard dolomitic limestone
	1.5	Light green shale
	1.0	Fossiliferous hard limestone
	0.5	Yellow marl
	>10	Yellow shale intercalated with limestone thin layers of 10-20 cm thickness.

Fig.P8: Lithostratigraphic section at hill located to the south of Menkaure Pyramid.

I-3.2. Petrographic study

Six samples were collected from the Pyramid plateau representing the parent rocks of the constructed pyramids in the area. The samples were thin-sectioned and studied under polarizing microscope. Moreover, acid job of 5% and 10% HCl was applied as to differentiate between the acid reactivity between limestone and dolomitized rocks. The studied rocks are belonging mainly to several carbonate types according to their texture and composition, as follows:

I-3.2. 1. Fossiliferous biomicrite

This facies is represented by microcrystalline carbonates (more than 80%), containing few quartz grains of medium to fine size floating within

the micrite matrix (Plate PI, Photo 18). Etching and replacement of quartz grains by micrite is recorded. Fossils of *Nummulites* sp. are recorded, while chambers are totally replaced by micrite with clear signs of aggrading size.

I-3.2.2. fossiliferous biosparite

This facies is similar to the former one except for the presence of larger crystalline crystals of calcite (sparite) as shown in Plate PI, Photo 19). The skeletal parts of fossils are totally replaced by sparite.

I-3.2. 3. Sandy micrite

This facies is composed of micritic matrix hosting coarse irregular grains of quartz with rims clearly etched and replaced by micrite (Plate PI, Photo 20).

I-3.2.4. Sandy sparite

Quartz grains are of medium to fine size, floating in well-crystalline rhombs of calcite spar (Plate PI, Photo 21). The calcite rhombs are seen as drossy one with vague zoning giving a clue towards low-magnesium and/or high magnesium calcite. Consequently, acid job using 5% and 10% HCl was applied indicating non-dolomitic composition.

I-3.2.5. Sandy dolomitic limestone

This facies assures the known reactions with acid job treatment indicating dolomite. Under the microscope, well-defined zoned rhombs are seen, etching and replaced the floating quartz grains (Plate PI, Photo 22). Ghosts of obliterated fossil shell fragments are difficult to trace, hence the adjective of (bio- and/or fossiliferous) was not applied.

I-3.2.5. Sandy fossiliferous dolomitic limestone

The skeletal parts of fossils and shell fragments reach about 15%. Most of these skeletal parts are replaced with rhombic dolomite crystals, while quartz grains of large size are also recorded (Plate PI, Photo 23).

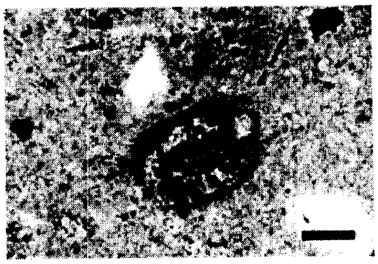


Photo 18

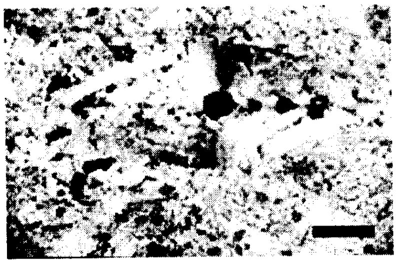


Photo 19

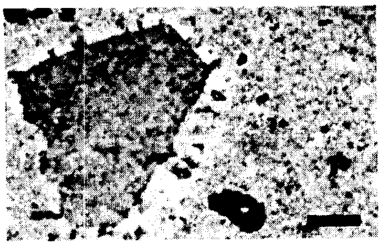


Photo 20

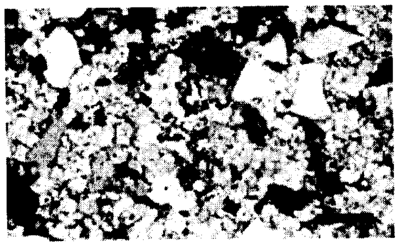


Photo 21

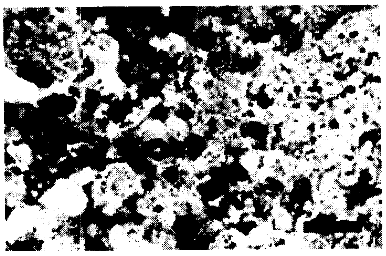


Photo 22

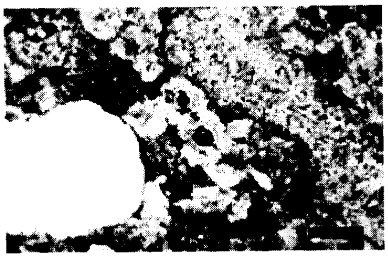


Photo 23

PLATE PI: Microphotographs for the studied rock thin sections, El Giza Pyramids Plateau

Photo 18: Fossiliferous biomicrite with few quartz grains, P.L., bar is 250μ. Photo 19: Fossiliferous biosparite composed of large fossil replaced by sparite crystals, N.C., bar is 250μ. Photo 20: Large quartz gains floating in micritic matrix, N.C., bar is 250μ. Photo 21: Fine to medium quartz grains floating in sparite matrix, sparite display perfect rhombic pattern. N.C., bar is 400μ. Photo 22: Fine quartz grains floating in dolomite skeletal rhombs showing clear zoning, N.C., bar is 400μ. Photo 23: Fossiliferous dolomite: fossils replaced by dolomite rhombs with medium quartz grains, N.C., bar is 400μ.

I.3.3. Structures in El Giza Pyramids Plateau

El Giza Pyramids Plateau is bounded on the northwest by the Upper Cretaceous Syrian Arc deformed Abu Roash area. The south to southeast dipping of the plateau rock units is related mainly to the deformed northwestward-located Abu Roash area. The dip amounts of the Eocene rocks forming the plateau range between 4° and 7°. The main structural features noticed in El Giza Pyramids Plateau are faults and fractures.

I.3.3.1.Faults

Detailed field study during this work indicates that El Giza Pyramids Plateau rock units are dissected by some remarkable faults. Most of these faults follow the NW-SE trend and they are mainly of normal type. Thr E-W is also detected but very scarce and show normal displacement. The planes of the NW faults showing southwest direction of dip, except the northern one that shows northeast direction of dip (Fig.P5).

It is noteworthy to mention that the NW trending faults in El Giza Pyramids Plateau are of prime importance where some of these faults could be related to some active faults following this trend in the nearby area. EGCO 1993 discovered an inferred fault following NW-SE direction nearby Cairo 500 KV substation which is located to the northwest of El Giza Pyramids Plateau. This fault is of tention gravity type with NE downthrown block and of remarkable extension where it could reach more than 50 km length. The southern trace extension is passing with the eastern boarder of El Giza Pyramids Plateau. Little more to the south, the epicenter of the 12th October 1992 earthquake is located at Dahshor. This earthquake had a magnitude of 5.9, it destroyed 8300 houses, 561 people were killed and 6500 were injured. The epicenter was located south west of Cairo near Dahshour, focal depth about 25 km (El Hakim and Basta, 1999).

So, it is very important to consider in the future detailed study for localization of capable active faults, as indication of recent tectonics (Salman, 1995) at the eastern zone of El Giza Pyramids Plateau and its southern extension. It is noticed during this study that

King Farouk Rest house, which is located at the eastern zone of El Giza Pyramids Plateau affected by a remarkable damage (Figs. P E1, P E2, P E3 and P E4). This damage could be related – in part - to relatively recent earthquake activity associated with other factors as nature of slope, rock type and weathering activity at El Giza Pyramids Plateau scarp edges. Also, the presence of plasting in nearby rock working quarries can form another hazarding factor.

Fig.P E1: Block sliding and damage in King Farouk Rest House, eastern zone, Giza Pyramids Plateau

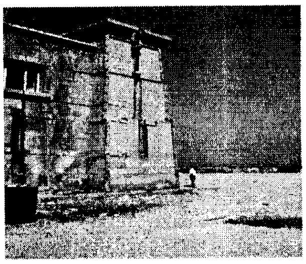


Fig.P E2:Cracks in the building of King Farouk Rest House, open fracture in the surface soil is noticed

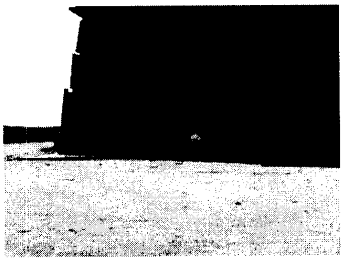


Fig.P E3: Fractures in the building of King Farouk Rest House, eastern zone of Pyramids Plateau

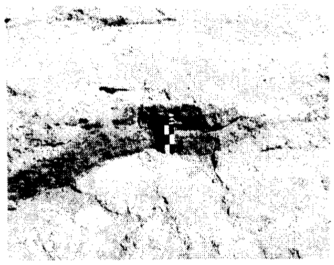


Fig.P E4: Very dangerous opened fracture, eastern zone, Pyramids Plateau

Fig.PJ1: Fractured marly limestone foundation bed, Khafre Pyramid

Fig.PJ2: Ferruginated complex fracture zone, marly limestone, Khafre Pyramid

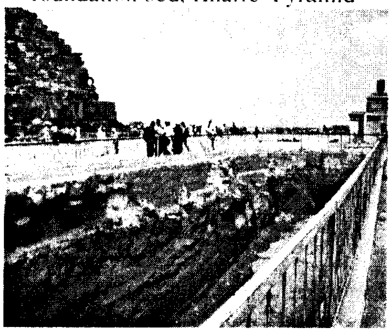


Fig.PJ3: Sun boat excavation showing major fractures, Khufu Pyramid, southern zone

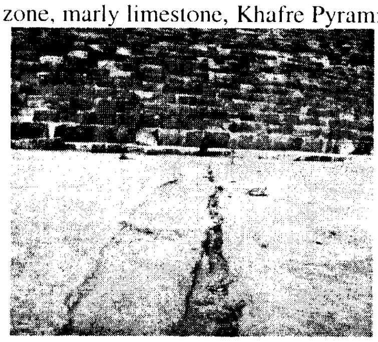


Fig.PJ4: Major fractures affecting the foundation bed rock, Khufu Pyramid, southern zone

Fig.PJ5: Close up major fractures, Sun boat excavation in the foundation bed rock, Khufu Pyramid, southern zone

Fig.PJ6: Major fracture trace on the foundation bed surface and it vertical extension, Khufu Pyramid, southern zone

I.3.3.2.Fractures

During the field work of this study, the attitudes of the fracturing structure (Fracture includes both joints and minor faults) around the three pyramids; Khufu, Khafre and Menkaure and Sphinx are recorded, statistically analyzed and rose diagrams are constructed (Fig.P8). It is clear from these diagrams that the NW-SE and WNW-ESE are the most prevailing fracturing trends around Khufu and Khafre pyramids. The NE-SW and ENE-WSW fracture sets are also predominating in the southern zone of Khafre Pyramid. At Menkaure Pyramid the N-S set is prevailing and the E-W set is common. In the Sphinx locality NW-SE, NNW-SSE and NNE-SSW sets are prevailing joint sets, while the ENE-WSW is a common fracture set (Fig.P8). It is noticed during field study of this work that these various joint sets show remarkable variations in their attitudes, mode of distribution, gapping size and their extension length (Figs: PJ1 to PJ12). These fractures are really representing remarkable hazards in the El Giza Pyramids Plateau.

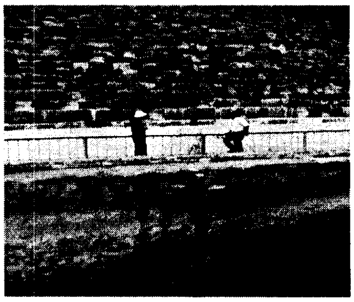


Fig.PJ7: Major fractures in Sun boat excavation with their surface extension bed rock, Khufu Pyramid, southern zone

Fig.PJ8: Major fracture zone affecting the surface bed rock, Khufu Pyramid, southern zone

Fig.PJ9: complex fracture zone affecting the surface bed rock, Khufu Pyramid , Eastern zone

Fig.PJ10: ferruginated fractures affecting the limestone associated with some alteration lense, Khufu Pyramid, Eastern zone

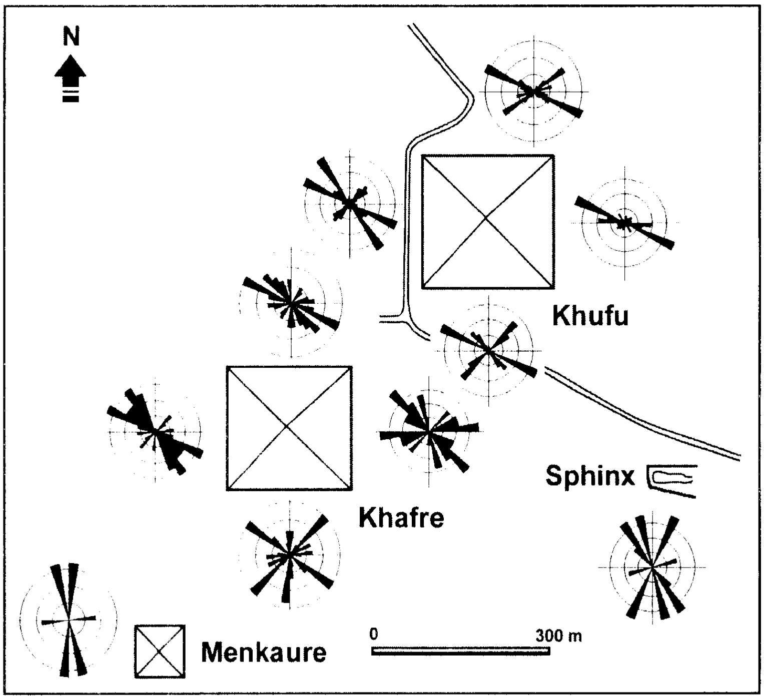


Fig.P8: Rose diagrams showing the fracture trends around El Giza Pyramids and Sphinx sites.

Fig.PJ11: complex fracture system affecting the surface bed rock, Khufu Pyramid , Northern zone

Fig.PJ12: Major fracture associated with complex fracture system affecting the surface bed rock, Khufu Pyramid , Northern zone

I.4. Hazards Affecting Monumental Sites

I.4.1. Hazards in El Giza Pyramids site

The field works during this study pay a great attention to the geological phenomena and their relation to the natural hazards which can bear a negative effect on the monumental sites.

I.4.1a. Hazards due to faults and fractures

El Giza Pyramids Plateau includes some number of major faults and several systems of fractures (joints and minor faults). These weak lines are following mainly two trends; NW-SE and WNW-ESE. The N-S, E-W and NE-SW are also common fracture trends (Figs.P5* to p7*). They are present in straight line form but sometimes show curvilinear shape or complex nature. They are mainly of tension type and sometimes show wide gapping.

The most interesting geologic structural phenomenon is that in some excavations (Sun boats) nearby Khufu Pyramid where there are major fractures of continuous nature (Figs.PJ7 to PJ12). Moreover, the traces of some of these fractures have been followed in the field and they are continuing under the great pyramid. These fractures can form a sort of hazard on the great pyramid site and the associated monumental units. These fractures can act as pass channels for the circulating water, along some of these channels salts and iron oxides

were noticed (Figs.PH6 to PH8). This is due to partial dissolving in the host rocks for iron components and salts and can be re-deposited with some fine clastic sediment in these channels. The increase in volume due to the deposition of these new substances can affect the stability of the foundation beds under some monuments in the pyramid monumental complex. Moreover, these fractures can facilitate the solution passage under some monumental structure and form some caves which negatively affect the stability of the site.

This structural phenomenon is also noticed around Khafre and Menkaure pyramids, but with some changes in fractures magnitudes (Fig.P8, PH3 and PH4).

During field study, EGCO teamwork visited the Mers Ankh Tomb to investigate the probability of continuation of some structural features downward. It is noticed that some fractures are found and affecting the inside parts of the tomb. Most of these fractures represent an extension for some surface joints and fractures (Figs. MERS 1 to MERS 8).

Fig. MERS 1: Fractures in the outer walls of the tomb G7530:EGCO [2005]

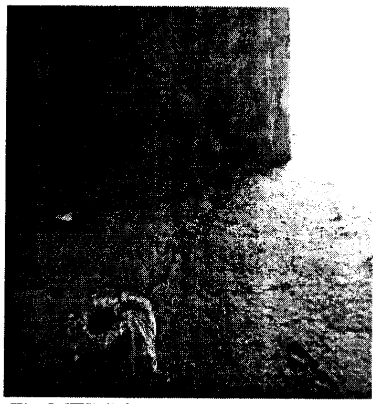


Fig.MERS 2: Fractures the entrance hall of the tomb G7530 with trace of curved joist at the wall :EGCO [2005]

ig.MERS 3: Teamwork members of EGC investigate the tomb G7530 [2005]

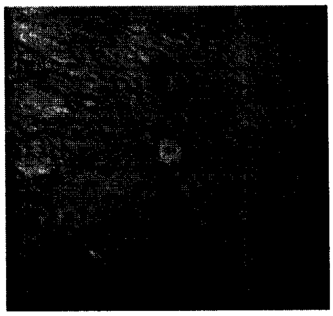


Fig.MERS 4:Vertical fracture inside the tomb G7530 [2005]

Fig.MERS 5: The northern room of the tomb"G7530 4th dynasty" [2005

Fig.MERS 6: Ferruginated fractures inside the tomb G7530 [2005]

Fig.MERS 7: Fracture across the northern room ceiling of tomb "G7530 4th dynasty" [A.Parania 1997]

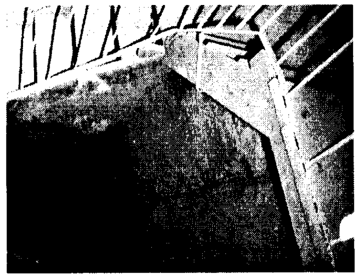


Fig.MERS 8: The entrance of the tomb-well [A.Parania 1997]

I.4.1b. Hazards due to sliding and rocks fall

This type of hazard is often due to various factors which include; nature of rock succession, type of the associated fractures and erosion. It is noticed during the field study in El Giza Pyramids Plateau that some major fractures have been split some bed rock and forming a real hazard. This is clear on the asphalt road facing the gate of Sphinx where there is a small ridge formed of hard limestone of El Mokattam Formation. It is noticed that this ridge includes several closely spacing dangerous fractures (Fig.PH1). This fracture set are often follow the major fault separating Khofu Pyramid from Khafre Pyramid (Fig.P5*). This fractured limestone can form a source of hazards where it is directly in contact with buss traffic road. For this hazard phenomenon, some supporting and fixation efforts for these fractures have been done (Fig.PH2).


Fig.PH1: Major fracture affecting the Rock succession under Khufu Pyramid and near to Sphinx


Fig.PH2: Supporting works for some dangerous fractured zone between Khufu Pyramid and Sphinx

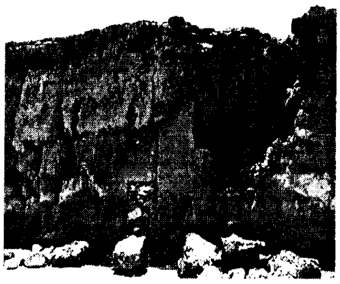


Fig.PH3: Dangerous site with some fallen rock blocks due to fractures, Chephren [Khafre] site


Fig.PH4: Hazard due to fracturing and weathering. A part of the bed rock can be fall down at any time, Khafre Pyramid

A remarkable hazard is noticed at the eastern scarp zone of El Giza Pyramids Plateau, where King Farouk Rest House is located. In this part rock sliding is clear due to compiled effect of structural features as faults and fractures, variation of lithologic units, weathering and probably earthquakes.

Similar observation is noticed to the west and north slopes of Khafre Pyramid where two small limestone scarps are present. At the cliffs of these scarps, several fractures are recorded where some rock boulders are fallen down (Fig. PH3). Some times a combined effect of fracturing effect and weathering form a real hazard in Pyramids Plateau (Figs. PH3 and PH4).

I.4.1c. Hazard due to rock weathering and karstfication

El Giza Pyramids Plateau is essentially composed of a sedimentary succession of limestone, argillaceous limestone and marls and some clay beds. This rock succession is subjected occasionally to rainfall and evaporation during temperate conditions. As a result of this situation these rocks are subjected to various types of weathering. Smoothing, polishing, scratching, pitting, boring, holing, differential erosion (Fig.PH5) and undercutting are the products of wind action on the bedrocks of the plateau (Soliman, 1997). These signs of weathering left their prints on these monumental sites and associated rock succession. The interaction of weathering agents, rock types and structural features take parts in the formation of karstification phenomena (Figs.PH6 to PH8).

The karstfication phenomenon in the Pyramids area has been studied in details. The lithological and structural characters of the limestone country rocks comprise the main factors controlling the surface and subsurface karst evolution (El Aref and Refai, 1987). This result has been confirmed during the present study (Figs.PH6 to PH8).

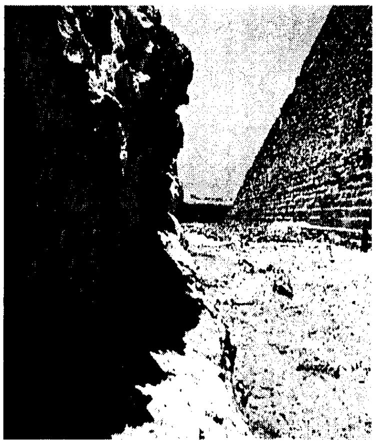


Fig.PH5: Strong deferential erosion in the associated country rocks, Khafre Pyramid

Fig.PH6: Ferruginous gathering (type of karsts), near Khafre Pyramid

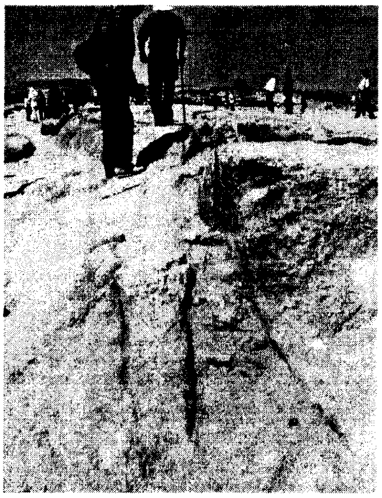


Fig.PH7: ferruginated fractures in limestone bedrock (type of karsts), Khufu Pyramid, Eastern zone

Fig.PH8: Ferruginous gathering (type of karsts), near Chephren pyramid

I.4.2. Hazards Affecting the Great Sphinx Site

I.4.2a Introduction

The Sphinx, sculpted out from the country rock, sits on and is attached to a rock cut platform that has been terraced back on three sides into an escarpment. To the west is the desert plateau upon which sits the great Giza Pyramids. To the east, and watched over by the Sphinx, is the River Nile flood plain. For many centuries only the head of the Sphinx was exposed and it was then surrounded by rocky outcrops and covered by wind blown sand. Archaeological excavations exposed the body and associated ruined buildings. The whole monument was then found to be more than 75m long and 12m high.

Excavations confirmed that the body and head were both carved out of solid rock. The head, rising above the surrounding plateau surface must have originally been an upstanding rocky knoll, perhaps a harder more durable rock bed. Excavations showed that as far back as the Roman Period major conservation work had been necessary around the base of the monument.

I.4.2b. Geologic units at the Sphinx site

The most important geologic feature is the type of sedimentary rock which forms the Sphinx. It is known by El Mokattam Formation which belongs to the Middle Eocene age, and is composed mainly from limestone and marl intercalations (Figs.S1* and S2*). Some clay beds exposure are noticed to the east of Sphinx site (Fig.S3*).

At the Sphinx site, El Mokatam Formation shows a distinct sedimentologic development which has been divided (Gauri, 1984) into three members representing the base, the thorax, and the neck and the head parts of the Sphinx. The base of the Sphinx consists of a massive, reefal limestone. This member is mostly covered by the veneer stones at the Sphinx. The thorax of the Sphinx is made of a 10 meters thick sequence of seven parallel bedded layers each ranging in thickness from 1 to 2 meters.

The beds of this member reveal cyclothemic pattern of sedimentation. In general, the sequence begins with clastic-marl layers with sparse foraminifera grading upwards into a Forminiferal micrite. Specifically, each bed has its lower layer more micritic and enriched in salts than the upper layer (Gauri, et al., 1987) while the higher layers become progressively less micritic and are enriched in skeletal grains. The upper most bed in the sequence, i.e. bed 7, is a clean packed biomicrite. Aigner (1981) suggested that the micrites were deposited in an open lagoon behind a nummulitic bank and received the coarse skeletal grains during periodic storms.

The head and the neck of the Sphinx have been carved from the upper member which is a nearly nine-meter-thick sequence. The lower one-third of this sequence forming mainly the neck is a marly limestone. The upper portion forming the head is a massive limestone inter - layered with four thin partings, each nearly 10cm thick, of somewhat softer limestone similar in composition to the limestone of the neck and the marly units in the middle member. In fact the strata of the upper member reflect on a larger scale the sedimentation pattern prevalent in the region where lower relatively more clastic composition is replaced in the higher beds by cleaner and skeletal-rich packstones.

It is noteworthy to mention that the presence of soft rocks as marl within Sphinx site form a real hazard on this important monument. This rock can be easily weatherd and disintegrated.

I.4.2c. Features controlling hazard in Sphinx site

The first factor controlling the hazard in Sphinx site is the prevailing **rock type**. The presence of soft marl beds in the succession of Sphinx makes its deterioration is rather easy. That is because; this rock is not resistant to various weathering and alteration phenomena. Figs.S4* and S5* show the effect of deferential weathering on the soft rocks (marl and marly limestone units) in the site of the Sphinx and in the upper part of its body.

Another important factor is the prevailing **fractures** which bear a remarkable hazard on the Sphinx site (Figs.S6 and S7). These fractures represent points of weakness which collect rain water,

subsoil water and the main source of the under ground water under the Great Pyramids and Sphinx.

The existence of two orthogonal, sub-vertical fracture groups in the rocks of the Sphinx has been detrimental to its durability. Where fracture, intersections occur towards the surface of the Sphinx, they separate wedge-shaped, blocks from the rest of the sculpture, causing massive loss of material from the core.

Major surface reduction of the Sphinx, however, is occurring due to **weathering** processes. The differential weathering has prepared the strata, especially that of the thorax into distinctly alternating protruding and recessed layers (Fig.S5*). This weathering can be attributed to crystallization pressures generated due to the repeated dissolution and crystallization of water soluble salts present in the stone, and more fundamentally to the influence of the pore size distributions.

Salts are generally the major cause of masonry disintegration in the arid climates (Cooke. 1981). Here, in spite of its scarcity, the moisture is able to condense as droplets of water in the cool of the night. This moisture forms concentrated salt solution, a process augmented by the hygroscopicity of the existing halite. The solution enters the pores under the influence of capillary force. At sunrise, as the water begins to evaporate, crystals of salt grow producing crystallization pressure. Often one can hear in the morning the sound of popping stone resulting from pressures produced under the surface layers.

Fig.S6: Highly fractured marl and limestone beds, Sphinx

Fig.S7: Limestone and marl bedrocks, with numerous fractures, Sphinx

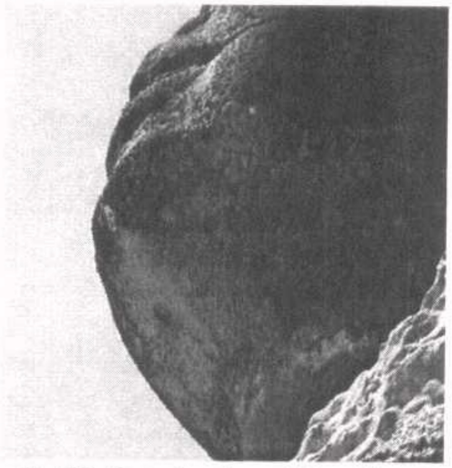


Fig.S8: Deterioration of the chin of Sphinx

Fig.S9: Deterioration of the left side shoulder of Sphinx

Fig.S10: The reminder color of Sphinx face

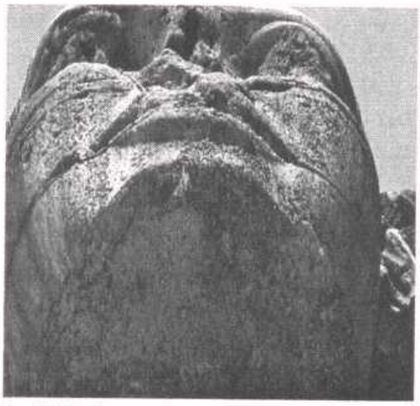


Fig.S11: Deterioration of Sphinx face

Fig.S12: Pitting in the chin of Sphinx

Fig.S13: Deterioration of stone coating right side of Sphinx

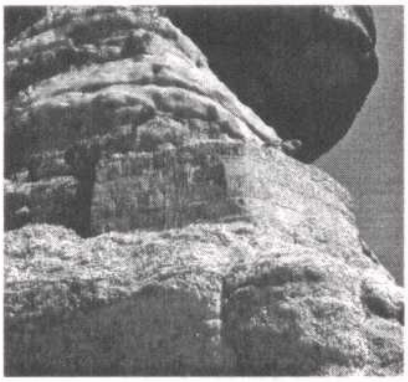


Fig.S14: Reconstruction of right shoulder of Sphinx

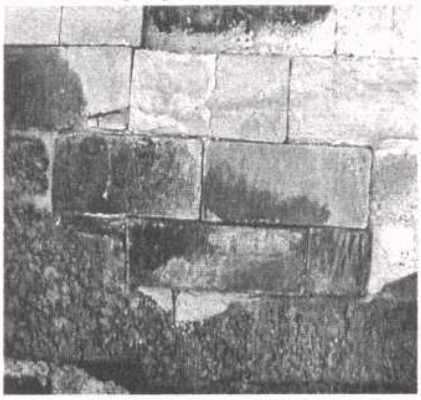


Fig.S15: High level of the under ground water, Sphinx

I.4.2d. Decay mechanisms in Sphinx

From the inspection of the Sphinx, the processes that seem to dominate the visually observed decay and deterioration (Figs.S8 to S15) are block failure and surface fabric spalling as a result of:

I.4.2d1. Wind turbulence

Where air moisture pollutants and suspended loads are involved in erosion of the surface, for example, around the neck. The degree to which capillary rise of ground moisture and a general rise of the water table, that is said to be responsible is unknown. Capillary rise of

moisture is a phenomenon generally found in walls to a maximum height of only 2-3.5m and not up to the 6-7m level of the neck.

I.4.2d2. Thermal stressing

Particularly acute cyclic reversals, caused by sun and rain. This process results in exfoliating flakes of the softer sandy limestone layers. Exfoliation is also a problem of salt enriched crusts that have different expansion and contraction characteristics from the unaffected rock fabric behind. Stress-strain development around open fractures may be severe due to high temperature environments that are known to develop in such places. Research into this phenomenon is presently being undertaken by the author at the excavations of Tel El Amarna.

I.4.2d3. Classic rock block instability

Resulting from sliding of 'wedges' on the Sphinx's left side (Fig.S9). This failure is due to rock instability as a result of fractures and differential erosion.

I.4.2d4. Water runoff causing

A. Surface migration of soluble salts and clay minerals and deposition of wind borne pollutants from modern Cairo.

B. Deposition of soluble salts (Figs.S10 and S11), perhaps including Calcite, Gypsum and Siderite and newly formed clay minerals in the fractures.

C. Seepage behind stone patches of various ages. This may create internal temporary ponding, accumulation of loose debris and salts and variable micro environments. The bonding of old to new fabric seems to be a cause of rapid decay. This may be a problem that is starting to appear in the very recent new stonework on the Sphinx's left side. On the left paw the top stone work has open fractures that allow water to penetrate behind the new patches lower down and were new fracture cracks are now to be seen. Fig.S15* show the effect of water seepage in the lower parts of Sphinx. The man made behaviors are also another cause for deteriorations in Sphinx.

PARET II: EL KHARGA OASIS

II.1. Introduction

El Kharga Oasis represents an important segment in the Western Desert of Egypt (Fig.K1). So, it is noteworthy to summarize some main interesting features in the Western Desert of Egypt as an introduction for El Kharga Oasis Area.

The Western Desert of Egypt covers approximately 700,000 km^2, which are more than two-thirds of the total area of the country. It is essentially a plateau desert that generally consists of three regional tablelands, which are the Paleozoic-Lower Cretaceous sandstones in the south, the Eocene limestone in the middle and the Miocene limestone in the north. The relief is highest at G. Oweinat (+ 1000 m.a.s.l.) and generally decreases towards the Nile Valley to the east and the Mediterranean Sea to the north. The relief is interrupted by several major depressions, which occupy about one-third of the total area of the Western Desert hosting the famous oases. The oasis, a depression in the desert comprising springs, wells and vegetation, which reflects the beauty, charm and diversity of nature surrounded by desert and high plateau. The significant oases are Siwa, Bahariya, Farafra, Dakhla and Kharga.

Kharga Oasis is the southern one in this cluster of depressions that ornamenting the barren Western Desert of Egypt. It is a unique natural depression in the Western Desert. Kharga Oasis (means in Arabic "point of departure"), is a depression of about 200 km long in the north-south direction and from 20 to 80 km width in the east-west direction. It is located between latitudes 24° and 26° N, and longitudes 30° and 31° E; covering an area of about 34,475 km^2. The depression is bounded by the Eocene limestone plateau from the east (eastern plateau) and north (northern plateau), where the high scarps form a sharp boundary to the depression floor. However, towards the south and west, the depression floor merges gradually into the Nubian Sandstone desert. A string of villages arranged on the middle part of the depression floor, the most important are El-Monira, Ginah, Boulaq, Baris and Duesh. Kharga Oasis lies about 600 km from Cairo and 230 km to the southwest of Assiut at the Nile Valley. It could be

reached through a series of good asphalt roads from Assiut City at the Nile Valley or from the neighboring Dakhla Oasis. It has presently a population of more than 100,000 people.

El Kharga city, as a product of the New Valley Project, is a modern and growing city with an ancient past. The Egyptian government has plans to make the area very attractive to tourism. The main square in town is Midan Nasser, where there is a statue of a woman holding her children. She represents Egypt, and her children are the oasis.

It was from El Kharga, the ancient trading route that the Persian King Cambyses' army of nearly 50,000 left Kharga in 525 B.C. and perished in a sandstorm.

Kharga used to be the last but one stop on The Fourty Days Road, the infamous slave-trade route between North Africa and the tropical south. Today, it is the biggest New Valley oasis and its modern city houses 60,000 people, including 1,000 Nubians who moved here after the creation of Lake Nasser.

Geomorphologically, the landscape is considered as either high plateau in the northern and eastern boundaries, or low-lying depression floor, meanwhile the pediment areas in-between are highly rough badlands. The landscape ranges in elevation between 460 m above sea level (a.s.l.), recorded at Gabal El Aguz (just to the south of Naqb Assiut) on the scarp face of the eastern plateau, and approximately zero level at Boulaq area (about 28 km to the south of El-Kharga town).

The present-day **climate** of the study area is extremely arid. According to the available data provided by "The Egyptian Meteorological Authority" in the past two decades, the maximum day time temperature fluctuates within wide limits, reaching up to 45-50°C in summer months, meanwhile in winter months, the minimum temperature may drop to as low as zero at night. The difference between day and night temperatures reaches up to 20-25°C.

Wind speed tends to be low in August, increases progressively in November to January and reaches a peak from March to May causing dust storms famously known as "El-Khamasin". The annual mean value of relative humidity is 39.3%. Generally, it is very much lower at noon than at either morning or evening. The atmospheric precipitation as rainfall is extremely scarce and insignificant (~1 mm/yr). Nevertheless, intermittent flashfloods may be so strong enough to cause road damage similar to that of November 1994, when Assiut-Kharga road was cut near Assiut Cement Company and Kharga-Dakhla road was cut nearly at km Post 98 in El-Zaiyat Plain. Although the oasis getting a very scarce rain, water is obtaind from springs and wells dug into the underlying porous Nubian sandstone. The thermal springs at Bulaq and Nasser villages to the south, are famous for water temperatures of up to 43°c and reputed to be suitable for the treatment of rheumatism and allergies. Camping facilities are available near both villages. Further south is Baris Oasis, the second largest settlement in Kharga. Houses designed in traditional Nubian style by Hassan Fathy remain uninhabited, local people refused to live in them because of their similarity to tombs and building stopped in the late 1960s.

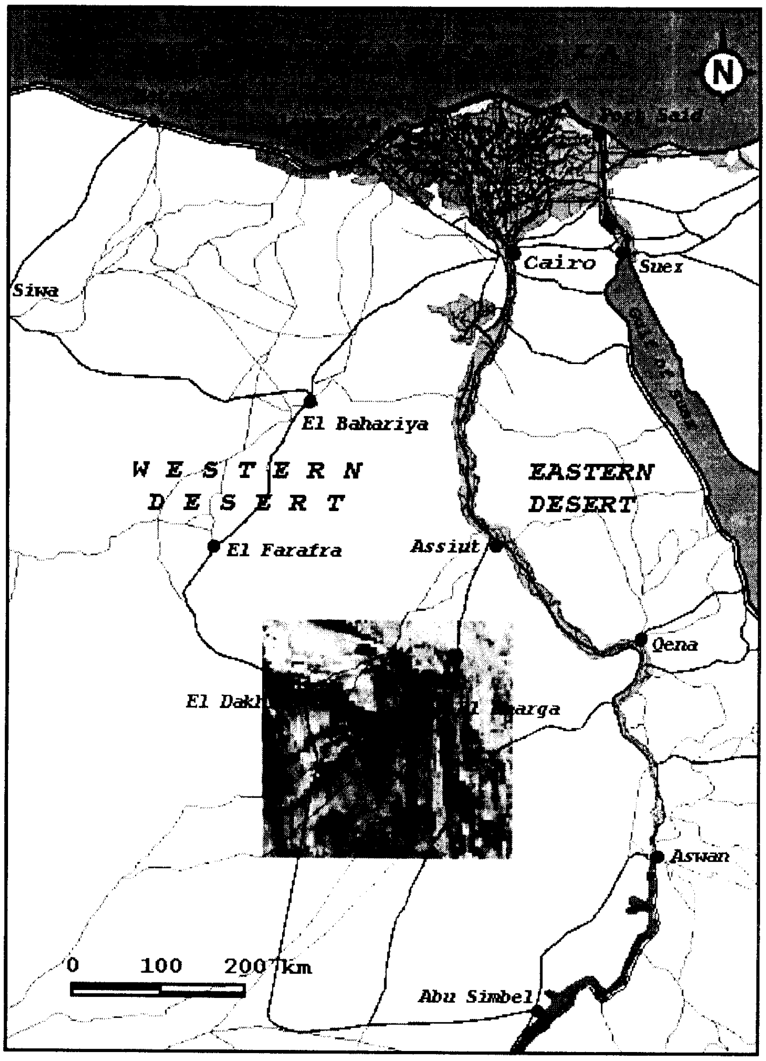


Fig.K1: Location map of a part of Egypt showing El Kharga Oasis area.

II.2. Geologic Setting

II.2.1. Regional geology

The geology of The Western Desert including El Kharga Oasis has been studied by many authors (Koetsch, G. and Yallouse, M., 1955, Salman, 1984, Salman, et.al., 1984, Said, 1962, Isawi, 1982, Said, 1990, El-Baz, 1992 and El Hennawi et al., 2005). From the regional geologic point of view, the area is covered by Upper Jurassic-Lower Tertiary sediments nonconformably overlying the Precambrian basement rocks. These sediments are well exposed on the depression floor and form a part of the eastern and the northern scarps. The following stratigraphic units are present, arranged from the depression floor upwards as follows:

The Nubian Formation (Fm), which has been recently subdivided into several rock units including the Sabaya Fm, the Maghrabi Fm and the Taref Fm. It is overlain upward by the Mut Fm, the Duwi Fm and the Dakhla Fm. The Lower Tertiary sediments, which unconformably overlie the above-mentioned rock units, comprise the following rock units from bottom to top: the Tarawan Fm, the Esna Fm and the Thebes Fm, which crop out along the eastern and northern scarps.

On the other hand, the Quaternary time is characterized by alternating periods of wet and dry climates, which resulted in several fluvial, lacustrine and aeolian deposits. These Quaternary sedimentary units will be treated in details when discussing the detailed geology of El Kharga Oasis. The structural elements of Kharga area are the result of typical stable shelf tectonics. Faults and, to a lesser extent, large-scale gentle folds are observed on the surface indicating differential block movements in the underlying basement. The resultant deformations in the overlying sedimentary cover are governed by its lithology and thickness.

From the geological structures point of view El Kharga Oasis area is affected by some remarkable structural features. To the north of latitude 25° N, nearly north-south trending faults of the normal

type are predominating. These faults extend over the depression and along the eastern and northern scarps as well. On the other hand, the east-west trending faults characterizing the south Kharga sector are subordinate here. The most important faults encountered in this sector are Qarn Ginah-Boulaq faults, Taref-Teir faults, Umm El-Ghanayim-Ghanima faults and the step faults along the northern Scarp. The extensions of these faults range from 4 to more than 30 km, following different trends that may deviate from the north-south trend to the NNW or to the NNE directions. The vertical displacements of these faults range from 5 to 225 m with the down-thrown blocks to either east or west (Ghobrial., 1967).

To the south of latitude 25° N., faulting is the dominant structural feature with greater density and persistence due to the relatively thin sedimentary cover. A group of parallel faults extending in a nearly East-West direction for distances up to 50 km divides the southern Kharga area into parallel blocks of variable width. The vertical displacements of rocks on the fault planes range from 10 to 50 m, occasionally accompanied by lateral shifts as in Abu Bayan El-Bahari and Abu Bayan El-Wastani faults, where granite hills are arranged along their courses in the depression. To the north, at Wadi El-Abd, on the scarp face and plateau surface to the east of Duesh, three faults of nearly east-west trend affect the Paleocene limestone beds of the Kurkur and Garra formations. A domal structure is associated with the northern fault, with Kurkur beds forming its core. To the NE of Baris, a similarly trending fault with about 20 m throw to the south, dissects the Paleocene beds on the scarp face and plateau surface. At Naqb Esna, the same fault system is observed cutting across El-Medawara domal structure with beds of the Dakhla Fm. at its core. This dominant east-west fault system is traced for several hundred kilometers to the east and west. As mentioned above, some centroclinal domes are associated with the dominant fault system on the plateau surface. The area of these folds reaches up to 25 km^2 and their beds are highly tilted near the fault lines. Up-arching of the shallow basement rocks in the south Kharga area seems as responsible for deforming and tilting the overlying sedimentary cover.

It is noteworthy to mention some of the recorded structural features are nearby some monumental sites. Minor telethermal barite-celestine mineralization occurs along parts of some of the recorded faults near the monumental cemetery of El-El Bagwat. In addition, several domal or basinal structures with steeply inclined flanks were developed in association with this group of faults. The folding of Qarn Ginah, located to the north of El-Ghueita Temple, could have been initiated in pre-Camparian times as indicated by the fracture system within its sandstone layers belonging to the Taref Formation.

II.2.2. Local geology

Kharga Oasis area (Figs. K2 and K3) is a depression that bounded from the north and the east by steep escarpments. Few isolated hillocks are found in the middle part of the depression. These are namely, Gebel Taref, Gebel El-Teir, Gebel Tarawan and Gebel Qarn Ginah (Figs.K5* and K10).

The study area was cut by a group of faults. The most important is the Taref-Teir fault, which extends from the western side of Gebel El-Teir in a southerly direction till near the northern end of Gebel Qarn Ginah, with total extension of about 31km in the N-S direction. This fault shows maximum amount of displacement of about 225m to the east in the vicinity of Gebel Tarawan. To the south, the area between Gebel Qarn Ginah and Boulq is cut by a group of faults running in a nearly N-S direction with amount of displacement ranging from 20 to 160m. Along with these faults, there is a group of isolated hillocks formed of layers belonging to the Taref sandstone member of the Nubia Fm. Some of these hillocks are intensively folded like Gebel Qarn Ginah meanwhile other hillocks show horizontal to slightly tilted stratification like the hillocks upon which Qasr El-Ghueita and Qasr El-Zayyan were constructed.

The relationship between the structures of the Kharga area, the ground water supply and then the present-day habitation and the past-occupied archaeological sits is clearly pronounced. Groundwater springs are restricted to the fault traces located in the middle lowest parts of the depression. Also, along these faulted areas, the Nubia

sandstone blocks are dislocated, emerging upward, forming raised hillocks. The archaeological sites are restricted these hillocks due to their rocky terrain allowing foundation of such big buildings and also due to their strategic high position permit the construction of Temples and garrison buildings.

El-Nadura, El-Ghueita and El-Zayyan Temples were constructed on such suitable hard sandstone ground. Meanwhile the unique Hibis Temple was constructed on unsuitable shale soft ground in a relatively low position. In the recent years, this unsuitable ground does not support the temple foundations especially in case of high subterranean water table conditions that cause differential swelling. So, this Temple is undergoing many dangerous problems, columns began to tilt, cracks appeared on the walls and salts seeped through the porous stones that threatened the temple with total collapse. Recently, ceiling walls (membranes?) dug around the temple to prevent subterranean water from seeping into the foundations.

Two fracture systems are recorded in the Taref sandstone member of the Nubia Fm., which exposed in the studied localities comprising Gebel Qarn Ginah, El-Nadura and El Bagwat area. One of the two systems consists of two sets of fractures which trend at azimuths of 50° and 150° that intersect at angles of about 80° and 100° (Fig.K4). This fracture system could be referred to as "older fracture system" or "pre-Lower Eocene fracture system" as it is recorded in the Nubia Fm. only. The other fracture system could be referred to as "younger fracture system" or "post Lower Eocene fracture system". This fracture system affects all the stratigraphic rock units till the Lower Eocene limestone cap of the plateau.

It is composed of two sets of fractures intersect at the same angles of the older fracture system and trending at azimuths of 5° and 105° in all the studied localities (Ghobrial, 1967).

Ripple marks are common in the sandy plains, which cover some parts of the depression floor. They reach up to 2m wavelength and their amplitude reaches about 15cm. They are locally known as "siuf el-raml", i.e. sand swords. The pebbles of these ripple marks

were used in the plaster covering the studied archaeological buildings.

The floor of El Kharga Depression is mostly covered by purple and green variegated shales that alternate in places with some sandstone and siltstone beds. These units are sometimes present in the form of low to moderate elevation hills like Gebel Tarawan to the north of Hibis Temple in the northern part and Gebel Qarn Ginah in the central part of the depression to the north of El Ghueita and Qasr Zayyan Temples (Figs K5* and K10*).

It is noteworthy to mention that the temples of El Nadura, El Bagwate, El Ghueita and Qasr Zayyan are situated on low hills formed of these sandstone shale intercalation units. These units form a limited area in El Kharga depression.

The most of the depression area is covered with Quaternary deposits of playa, sabkha, sand sheets and sand dunes (Figs.K5* and K10*).

The structure of the depression is simple. The most striking structural feature is the presence of large north south fault, which runs in the center of the depression for about 100km (Ghobrial, 1967). The studied monumental sites are almost situated near the pronounced structurally affected areas at the mid-depression. This is due to the presence of the flowing springs as the main water resources suitable for permanent settlement in these areas.

The studied monumental sites show different geomorphic setting. Meanwhile ElNaduraand Qasr El Ghueita Temples are located on hilltop fortress; the other two Temples (Hibis and Qasr El Zayyan) are located on the peniplained floor of the depression. On the other hand, the cemetery of El Bagwat occupies hilly area where the chapels are distributed on hilltops. The shallow groundwater table is greatly affect Hibis Temple as it is located at the same level of the neighboring palm grove as shown in figure K6.

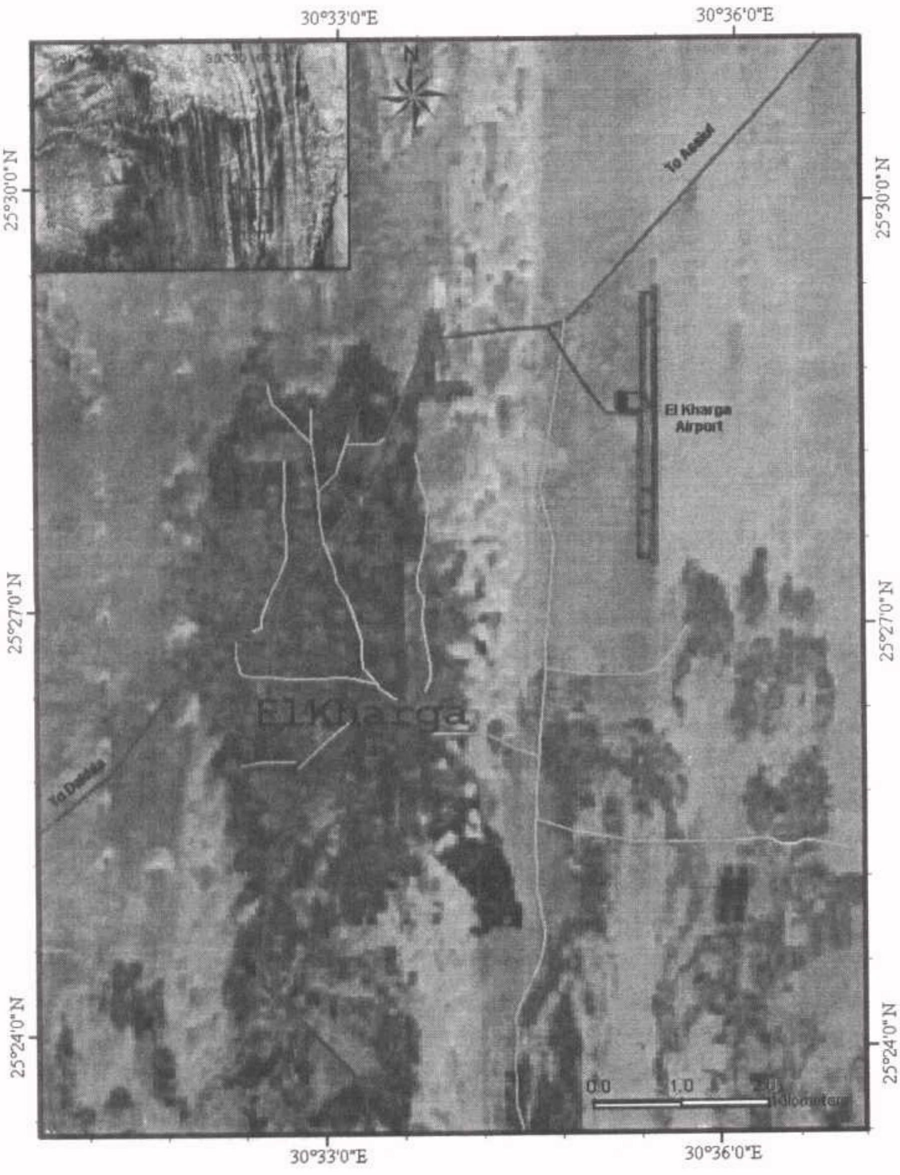


Fig.K2: Space image for the northern part of El Kharga Oasis including some monumental sites

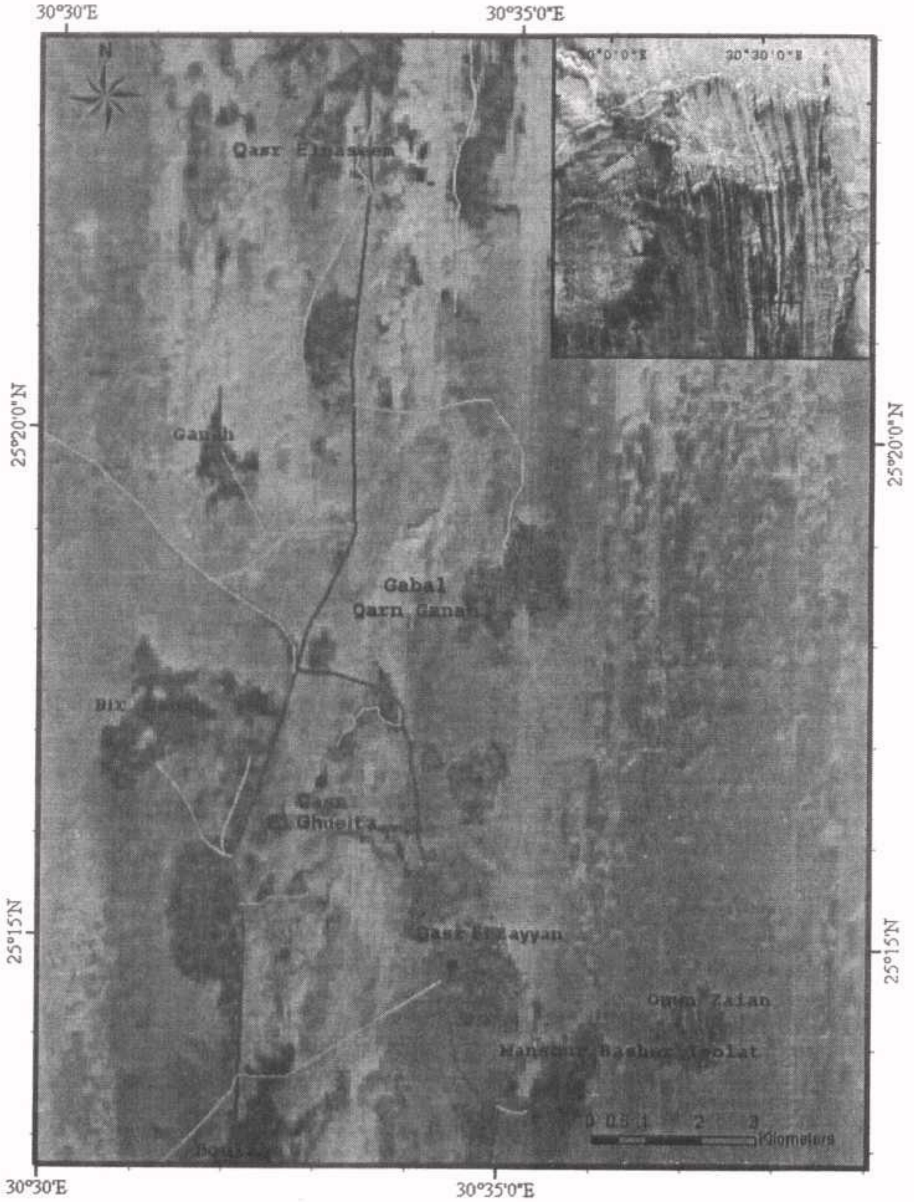


Fig.K3:Space image for the central part of El Kharga Oasis including some monumental sites

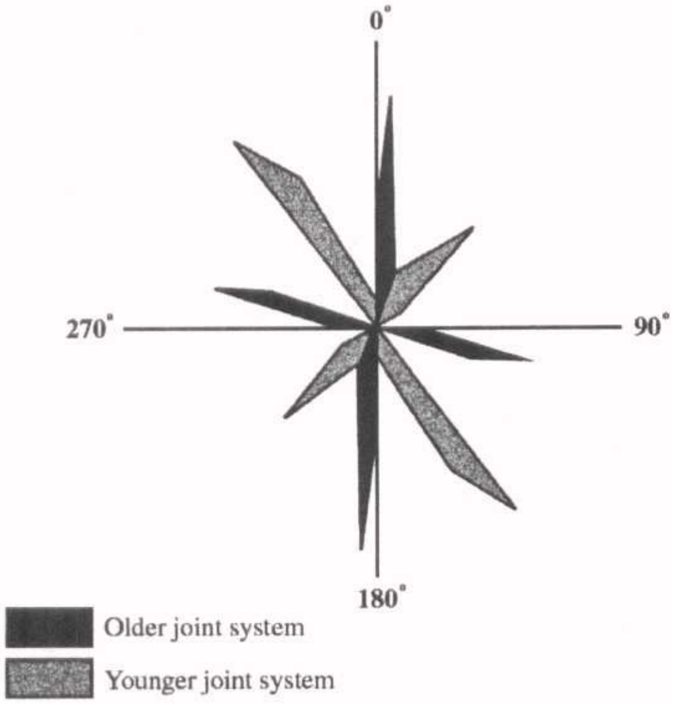


Fig.K4: Frequency distribution diagram of the trends of fractures in the Nubia Fm. exposed in the studied localities (After Ghobrial., 1967).

Litho-stratigraphic sections were studied in the hilltop monumental sites comprise El Bagwat Cemetery,El Nadura Temple and Qasr El Ghueita. The mid-depression hills where the monumental sites are founded are composed entirely of sandstone and siltstone beds alternating with variegated shales as illustrated in the following lithostratigraphic sections (Figs.K6, K9 and K12).

The Quaternary deposits form small outliers, which can be distinguished according to their lithologic characteristics into: gravel fills terraces and sheets, tufa deposits, sabkha deposits, playa deposits and sand dunes (Figs.K5* and K10*).

The different gravel accumulations are widely developed on the Eocene plateau surfaces as gravel-fill deposits and at the feet of all scarps as channel-fills, terraces and sheets of varying thicknesses. Gravel sheets form patches of embedded, non-indurated gravels at mouths of the channels draining the scarp faces.

Tufa deposits are well developed at Kharga Oasis along the eastern scarp face at Naqb Assiut, Naqb El-Rufuf, Naqb Boulaq and Naqb Esna, as well as encountered at Ain Amur on the northern scarp face. They spread over the scarp faces, wedging out at their feet into fan-like masses, which are mostly dissected by palaeowater courses. The thickness of the deposits reaches more than 10 m of porous or laminated freshwater carbonates. They provide evidence for possible groundwater seepage during previous wet periods.

Sabkha deposits of Kharga Oasis comprise salt encrusted sediments deposited in the central low-lying shallow basins. These shallow basins are structurally controlled, being excavated by weathering along the fault-dissected areas at the central parts of the depression. At such sites, freshwater to saline environments were present during parts of the Quaternary

The Quaternary playa deposits on the depression floor are horizontal friable alternating bands of medium to fine clastics. They are composed of mixtures of sand, silt and clay of all proportions that accumulated in shallow isolated deflation basins excavated in the depression floor bedrocks. These playa deposits occupy the lowest topographic parts in the depression were considered as the "Kharga floor deposits".

Sand dunes are best developed along the Kharga depression and they really represent a remarkable hazard on the monumental sites in El Kharga Oasis.

II.2.3 Petrography

I- Involved Samples in Petrographic Study (Kharga Oasis Temples and Surroundings)

During the field investigation trip to the Kharga Oasis and its

surroundings, sampling, field descriptions and measurements were the main goal for the group. Moreover, recording of the deterioration rates in the monumental sites even after treatment with conservation materials were documented and samples as to test their durability and effectiveness against natural weathering parameters (mechanical and chemical). The following table summarizes the used symbols designating each location, in addition to both sample numbers and observatory remarks for the sample type.

Symbol	Location	No. Samples	Remarks
Z	Qasr El-Zyyan	4	Plaster material
GH	El-Ghewita	10	Mud bricks and plaster
N	El-Nadura	4	Plaster
H	Hibis	6	Building stone and plaster
B	El-El Bagwat	3	Seif dune plaster
GQ	Gabal El-Qarn	2	Building stone

II.2.3.1: Petrography and digenetic features

The petrographic study was based on 29 samples representing the studied monumental sites at Kharga Oasis and its surroundings. The samples were thin-sectioned on a cool state to avoid mineral alterations. The studied thin-sections covered the following lithofacies in the studied locations:

1- Quartz arenite (QA): mainly made up of medium to coarse quartz grains.
2- Calcareous quartz arenite (CQA): fine to medium quartz grains cemented by micrite or calcite.
3- Phosphatic quartz arenite (PhQA): fine to medium quartz grains containing 30% of Phosphatic rock fragments as cellophane.
4- Gypsiferous quartz arenite (GQA): coarse to medium quartz grains cemented by well crystalline swallow-tail gypsum crystals.
5- Ferruginous quartz arenite (FQA): fine to very-fine quartz grains floating in ferruginous cementing material.
6- Bio-clastic limestone (BCLM): Recrystallized fossiliferous limestone.

7- <u>Argillaceous mud stone (AMS):</u> very fine quartz grains floating in mud.

8- <u>Seif dune plaster (SDP):</u> composed of different sized-quartz grains from near-by local dunes.

The above recorded lithofacies cover the studied locations, these are: Qasr El-Zyan; El-Ghewita; El-Nadura; Hibis; El BagwatTemples and Gabal El-Qarn. The following is the detailed description of the encountered petrographic features with emphasis on the recognized digenetic alterations.

<u>1- Quartz arenite (QA):</u>

This type is represented by different sized-grains of quartz (Plate KI, Photo 1) exhibiting straight extinction indicating their unimodal origin without avoiding source admixtures and mainly of plutonic origin (Plate KI, Photo 1, white arrow) as documented by the presence of well crystalline spinel crystal). Compaction is easily recorded I the examined thin-sections (Plate KI, Photo 2, solid black arrows). The degree(s) of compaction ranges from arched contacts till engulfing, while pressure growth expressed by brecciation of quartz grain can be detected (Plate KI, Photos 2 - 4, solid arrows). Secondary overgrowths of silica are a common feature (Plate KI, Photos 1 and 5, solid black arrows). Silica is the main cementing agent and believed to result from pressure stresses. Quartz grains display either free-inclusions or containing well crystalline spinal crystal (Plate KI, Photo 5, red solid arrow).

<u>2- Calcareous quartz arenite (CQA):</u>

This lithofacies indicate that quartz grains are of fine-sized tightly compacted grains, floating in a calcareous cement of calcite (Plate KI, Photo 6). Cementing material did corrode quartz grains, while relics of quartz grains can be detected.

<u>3- Phosphatic quartz arenite (PhQA):</u>

This lithofacies was recorded as fine phosphatic debris as matrix and sometimes contains either phosphatic fragments or concretions of quartz grains as a ghost of previously existing fossils (Plate KII, Photos 7-9, white arrows). Sometimes, recrystallized plantnktons can be seen as dumped framework in the matrix (Plate KII, Photo 9, solid arrow) The phosphatic rock fragments are mainly

of collophane type as parts of bones (Plate K II, Photo 8, white arrow).

4- Gypsiferous quartz arenite (GQA)

This lithofacies represent plaster material cementing quartz grains with clear signs of etching and corrosion with different grades (Plate KII, Photo 10). Recrystallization stages of gypsum crystals are displaying well developed interlock pattern constituting perfect material for re-building deteriorated skeletons in monumental sites (Plate KII, Photo 11).

Closer views for the used material as plaster, the locked pattern of gypsum indicate etching of the wood parts and quartz concretions (Plate K III, Photo 12, white and black solid arrow respectively). Severe etching and replacement was also recorded and were seen as replacement of wood part (cellulose) by silica showing inward to outward process, while ghost of the original outline can be traced (Plate KIII, Photo 13, white solid arrows).

5- Ferruginous quartz arenite (FQA):

This lithofacies represent another plaster material used in deteriorated monumental parts. The used material is seen composed of fine uniform quartz grains indicating compaction as indicated by the aligned pattern (Plate KIII, Photo 14). Two main components were detected in the examined thin-sections seen as a lower part displaying the ferrugenated part separated from the upper one by argillaceous richer part difference even in tone (Plate KIII, Photo 14, solid white arrows).

6- Bio-clastic limestone (BCLM):

This lithofacies is mainly of calcareous composition, composed of recrystallized bio-clasts. The bio-clasts are represented by sparry calcite crystals replacing the former fossils and even the micritic matrix are displaying Recrystallization phases of neomorphism (Plate KIII, Photo 15).

7- Argillaceous mud stone (AMS):

This lithofacies represent the paste material used for the deteriorated interior ceilings. It is composed of vary-sized quartz grains tightly compacted with mud material (Plate KIII, Photo 16). No signs of etching between the mud and the framework of quartz grains. Among the examined thin-sections, a record of the presence of some sedimentary rock fragments (mainly broken fossils) was detected.

8- Seif dune plaster (SDP):

This lithofacies represent a local type of plaster material used on a wider scale at El Bagwat and El-Nadura Temples. It is composed of dune sand (variable sizes), derived from seif dunes surrounding the area. The quartz grains are well rounded and polished, of different origins (single, composite and polymictic) showing straight and unduelose extinctions (Plate KIII, Photo 17). The framework is cemented with calcareous material admixed with finer fragments.

Photo 1

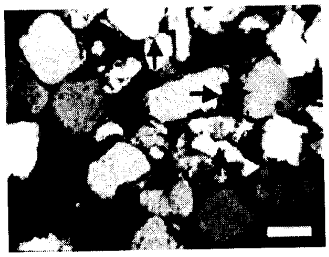


Photo 2

Photo 3

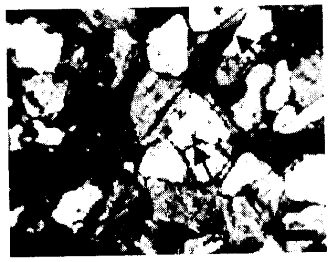


Photo 4

Photo 5

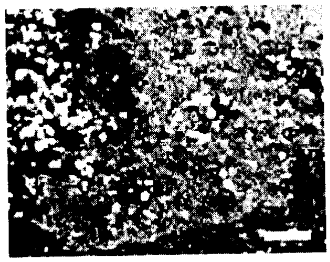


Photo 6

Plate KI: Microphotographs for the studied rock thin sections, El Kharga monumental sites

Photo 1: Quartz grains of uniform size and straight extinction with secondary overgrowths (solid arrows) and spinal crystal (white arrow), Nicols Crossed (N.C.), bar is 400μ. Photo 2: Tightly compacted quartz grains displaying arching till embayment (solid arrows), N.C., bar is 400μ. Photo 3: Engulfing feature between quartz grains, N.C., bar is 400μ. Photo 4: Brecciated quartz grains (solid arrows), N.C., bar is 400μ. Photo 5: Secondary overgrowth of silica (solid black arrow), red solid arrow indicate spinal inclusion, N.C., bar is 400μ. Photo 6: Fine quartz grains floating in calcareous cement that corrode quartz grains, N.C., bar is 250μ.

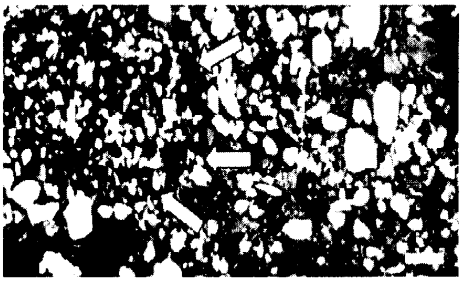


Photo 7

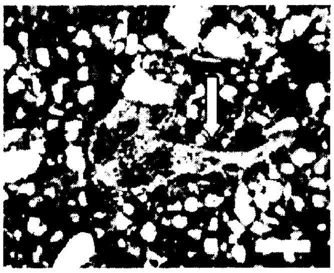


Photo 8

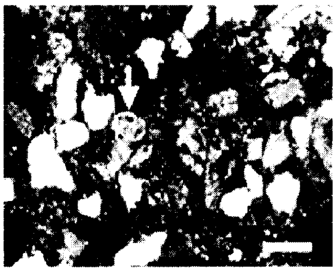


Photo 9

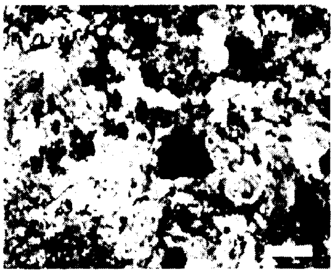


Photo 10

Photo 11

Plate K II: Microphotographs for the studied rock thin sections, El Kharga monumental sites

Photo 7: Panoramic view showing concretion replaced by quartz (white arrows) dumped with quartz grains in phosphatic matrix, N.C., bar is 250μ. Photo 8: Collophane phosphatic rock fragments (white arrow), N.C., bar is 250μ. Photo 9: Matrix of phosphatic rock fragments, solid arrow points to recrystallized planktons, N.C., bar is 400μ. Photo 10: Gypsum crystals cementing quartz grains with signs of corrosion, N.C., bar is 400μ. Photo 11: Recrystallized gypsum crystals as plaster material, N.C., bar is 400μ.

II.2.3.2: Adopted plaster materials versus archeological site

Archeological sites in El Kharga Oasis did witness different types of plaster materials (welding) aiming to hinder the deteriorating monuments covering: rooms, architect style, fractures, colors and most important the flesh part at tombs. Kharga Oasis comprises different age civilizations started from pharaonic till Islamic ages. Each civilization was adopting a certain style of building material and engineering style for construction. Some of the adopted materials were suffering from geologic deformational features as cracks, micro-fractures etc. . These weaker parts formed the path way for rapid deterioration leading to partial and even total collapse of these monuments. Hence interference to stop or to slow down the rate(s) of such deterioration enhances researches for proper plaster material choice. The chosen samples for petrographic approaches did cover through the microscopic investigations different parts of the adopted plaster materials.

The studied thin-sections from the different locations indicate that three main types were used as plaster material. The first one is gypsum (widest in applications); the second in abundance is sand grains from seif dunes and calcareous lime as the third one.

Gypsum was applied in many cases as a plaster welding material between deteriorated original parts made up of wood or stones (Plate KII, Photos 10 and 11 and Plate KIII, Photos 12 and 13). Gypsum as a welding material is efficient whenever the welded materials are of alkaline range e.g. concrete, but with calcareous and wood materials a secondary corrosion and replacement phases were recorded within applications of no more than two decades (Plate KII, Photo 11 ad Plate KIII, Photos 12 and 13). The corrosive rate(s) were not tested versus time since application; particularly most of the skeletal structures were using a coating material of wood parts and straw in many instances (El Bagwat). It is highly recommended to test the gypsum plaster material particularly in highly arid regions since its hardness is weak against corrosive wind action as in Kharga Oasis. Local materials as sand grains from seif dunes would formulate environmental re-balancing with the building stones (El-Ghewita)

since it fits the local environments and maintain harmony with the originally used stones. Signs for secondary overgrowths of silica and engulfing were easily detected in the studied thin-section (Plate K I, Photos 1-5). Mixing of the seif sand grains with argillaceous material is another widely used plaster material showing uniformity with the welded stone (Plate K II, Photo 7 and Plate K III, Photos 16 and 17).

Application of lime was used from local materials as soft welding material and probably temporarily plasters material (Plate K II, Photo 9 and Plate K III, Photo 15). No signs of alteration and/or corrosion were detected by the used lime material.

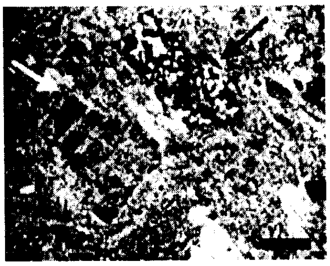


Photo 12

Photo 13

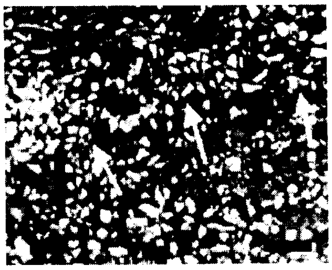


Photo 14

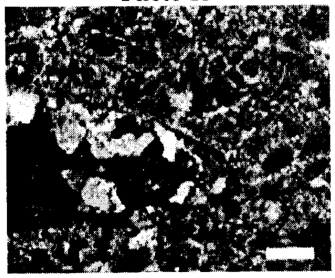


Photo 15

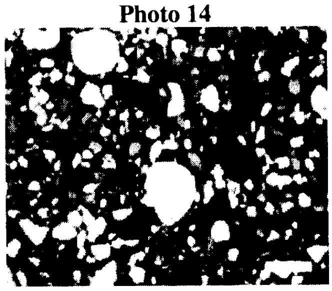


Photo 16

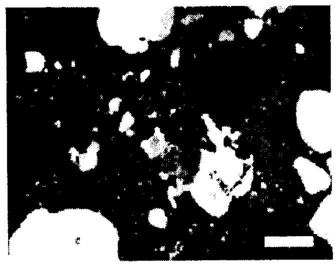


Photo 17

Plate KIII: Microphotographs for the studied rock thin sections, El Kharga monumental sites

Photo 12: Wood and concretion cemented by gypsum plaster, N.C., bar is 400μ. Photo 13: Wood part replaced by silica from inward to outward manner, N.C., bar is 400μ. Photo 14: fine quartz grains dumped in ferruginated matrix (lower) and upper argillaceous rich part separated by solid white arrows, Polarized Light (P.L.), bar is 250μ. Photo 15: recrystallized fossils displayed by sparry calcite, N.C., bar is 250μ. Photo 16: Vary sized quartz grains in mud, N.C., bar is 250μ. Photo 17: Well rounded different sized quartz grains of different origins, N.C., bar is 400μ.

II.3. Monuments in El Kharga Oasis

II.3.1. Introduction

The monumental sites are spread in El Kharga Oasis area. Outside the main center is the temple of **Hibis** which built on the site of an 18th dynasty settlement of Saites, Persians and Ptolemy one of the few Persian monuments in Egypt, the 6th Century BC Temple is well-preserved with painted vultures and huge relieves of Darius greeting Egyptian Gods on the outer walls.

Ten kilometers away, the Necropolis of **El Bagwat** contains 263 mud-brick chapels with Coptic murals, including the Chapel of Peace with images of Adam and Eve and the Ark on its dome and the Chapel of the Exodues with frescoes of Pharaonic troops pursuing the Jews led by Moses, out of Egypt. Pharaonic monuments include **Qasr el-Ghueita** Temple which dates from 522 BC and the temple of Amenebis. To the south of Qasr el Ghueita Temple **Qasr El-Zayyan** Temple is located.

Ancient monuments include the temple of **Duesh**, dedicated to Isis and Serapis. Its name derives from Kush, the ancient Sudanese capital which traded with Egypt along the Nile. Archeologists are still unearthing the ancient city of Kysis and elaborate system of clay pipes and abandoned Christian church, suggest that Kysis was abandoned when its underground springs dried up but the exact date remains a mystery

Historical, references of Kharga Oasis go back as far as the Old Kingdom, but little evidence remains in Kharga today of life in Pharaonic times. Throughout its history Kharga seems to have been the place to where undesirable inhabitants of the Nile Valley were banished, the fierce summer heat, devastating winds and remote location making it an ideal place of exile and many records survive from the New Kingdom to illustrate this. There are also many historical accounts of expeditions sent to quell the rebellious inhabitants of the oasis.

During the Third Intermediate Period, Egypt's Libyan rulers began to take an interest in the Oases, improving the desert tracks and making an effort to bring the marauding desert tribes under control. From this time onwards, Kharga began to prosper and two Temples dedicated to the Theban triad were built at Hibis and El-Ghueita during the Late Period. By then it was securely attached to the Nile Valley and when the Romans came to Egypt they increased the prosperity of the oasis by creating new wells, cultivating many crops and building a series of "fortress settlements" for protection of the caravan routes. These Roman "fortresses" are especially numerous in the Kharga Oasis, where the Darb el-Arba'in (the forty-day road) which ran north to south between Assiut and the Sudan, was the most important trade route. This was later to become part of the infamous slave-trade route between North Africa and the tropical south.

Hibis Temple, located just outside El-Kharga town, was built on the site of an 18th dynasty settlement of Saites, Persians and Ptolemy. It is considered as one of the few Persian monuments in Egypt. The 6th century BC Temple is well preserved with painted vultures and huge relief of Darius greeting Egyptian gods on the outer walls. Two kilometers away, the Cemetery of El Bagwatcontains 263 mud-brick chapels with Coptic murals, including the Chapel of Peace with images of Adam and Eve and the Ark on its dome and the Chapel of the Exodues with frescoes of Pharaonic troops pursuing the Jews led by Moses, out of Egypt.

Hibis Temple is the best-preserved Temple in the Western Desert. It was built by King Darius I in the 27th Dynasty (525 BC). It was dedicated for the worshipping of the triad of Thebes, Amon, Mut and Khonso. It was also used as a garrison until 330 BC. And it contains evidence of use in later periods, including the early Christian period. There are signs that Muslim Pilgrims used it later as a route to Mecca. The temple was constructed from local limestone blocks on the edge of a small sacred lake.

This Temple, which was excavated and restored by the New York's Metropolitan Museum of Art earlier this century, has suffered from a locally rising water table. It has recently been repaired by the Egyptian Supreme Council of Antiquities, and was scheduled for

removal to another site due to problems with ground water. But great debate is rise about what is more suitable, dismantle or just massive consolidation and restoration. The temple is currently closed to tourists and only the outer parts may be visited

The early Christian Cemetery of El Bagwatis located about 3 km from the center of El-Kharga town and one km north of the temple of Hibis. It may be the oldest major Christian cemetery in the world, dating back to the 4th century AD. The chain of at least twenty-mud brick fortress, possibly built on top of pharaonic ruins, is varying in size and function. Some are large settlements or garrison towns, while others are small desert outposts, but most of them lie close to the road crossing the oasis, following the ancient trade routes. The Romans went to great lengths to secure water in the oasis, although little is known about how or when the original boreholes were drilled. Some are over 120m deep and continue to be used today. They also built long underground aqueduects up to 50m deep in the water-bearing sandstone. Many of the Roman fortified settlements are situated strategically on hilltops and several, such as Qasr Duesh, Qasr El-Ghueita, El-Nadura, and Qasr El-Zayyan incorporated Temples and large communities of people. These chains of fortress were likely facilitated the development of agricultural colonies, which depend on tapped underground water supplies.

The fortress of Qasr el-Ghueita is located at about 3km to the east of the main road and about 18km to the south of El-Kharga town, on the crest of a sandstone hill from where it commands a strategic view over the desert plain.

Qasr El-Zayyan was known in ancient times as Takhoneourit, which the Greeks called Tchonemyris, meaning "the great well". It lies about 30km to the south of El-Kharga town and not far from the fortress of Qasr el-Ghueita.

II.3.2. Studied Monumental Sites

II.3.2.A. Hibis Temple site

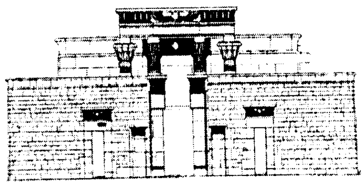


Fig.HI.1: Drawing of the Hibis Temple in El Kharga Oasis

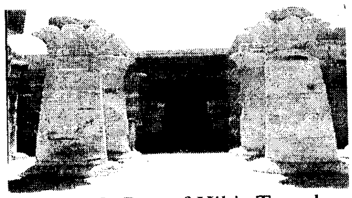


Fig.HI.2: Part of Hibis Temple

II.3.A1. Introduction

The largest and best preserved temple in the Kharga Oasis is the temple of Hibis (Figs.HI.1, HI.2, HI.3, HI.4 and HI.5), probably because it was buried in sand until the excavators dug it out early during the twentieth century. In fact, it is one of the finest Temples anywhere in Egypt from the Persian period. Hibis, from the Egyptian Hebet, meaning "the plough", is located just over two kilometers north of the modern city of Kharga. The town associated with the temple, known as the Town of the Plough, was in ancient times the garrisoned (known as the fortress of Qasr el-Ghuieta) capital of the Oasis, easily covering a square kilometer. It lay in the valley between the foothills of Gebels al-Teir and Nadura. We know very little about the ancient town, though early excavations did unearth a few houses with vaulted ceilings and fresco paintings.

This temple, which was excavated and restored by New York's Metropolitan Museum of Art earlier this century, has suffered from a locally rising water table. It has recently been repaired by the Egyptian Antiquities Service, and was schedueled for removal to another site due to problems with ground water. However, recently Zahi Hawass has decided that the temple can be restored in-situ. The temple has also recently been the object of a five-year epigraphic survey carried out by an American team led by Eugene Cruze-Uribe.

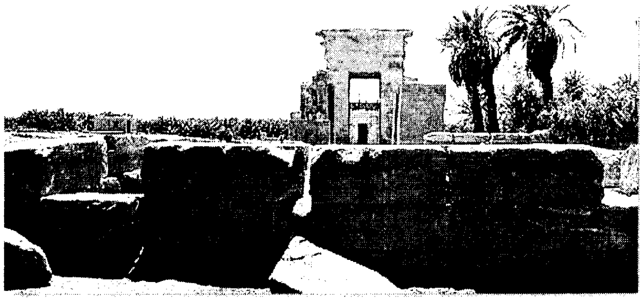


Fig.HI.3: The temple of Amun at Hibis is approached through a series of gateways showing wet land at its base

The temple is dedicated to the Theban triad, consisting of the gods, Amun, Mut and Khonsu, who's reliefs are in very good condition. The temple as well as the fortress it was built within, dominates the desert road from the south by sitting on a volcanic outcropping. During ancient times, the temple was surrounded by a lake that has now disappeared. The temple was begun by Apprise in 588 BC, during the 26th Dynasty so the foundation may date somewhat earlier. It was completed by the Persian, Darius I in 522 BC. Later, Nectanebo II built the colonnade, and other additions were made during

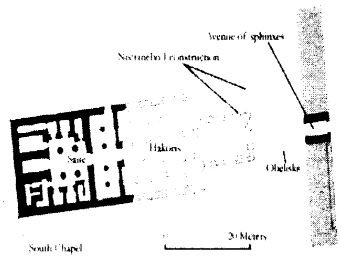


Fig.HI.4: Floor plan of Hibis Temple

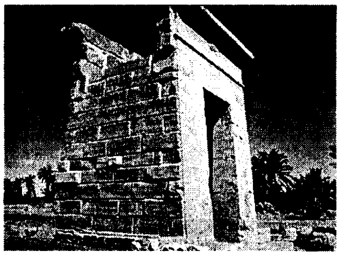


Fig.HI.5:A part of Hibis Temple

the Ptolemaic period during the fourth century, a church was also added along the north side of the portico (Ref: http://www.touregypt.net/elkharagatop.htm.).

There are many aspects of the temple's plan, construction and decorations that are unusual. The temple was built from the speckled local limestone in an east/west orientation. A sphinx-lined approach leads through a series of gateways beginning with one built by the Romans. Inscriptions on this gate contributed greatly to our understanding of Roman Rule. Created in 69 AD, they provide information on various topics, including taxation, the court system, inheritance and the rights of women. Nectanebo I and II surrounded the temple with a stone enclosure wall which, at the front enclosed a monumental kiosk with eight columns. Because of the excessively wide span of 7.4 meters, the kiosk had to be roofed with wooden rafters. The composite capitals in the kiosk and hypostyle hall are the earliest known in Egypt. In front of the kiosk are two obelisks at the end of the avenue of sphinxes.

In the front of the temple is an early form of pronaos with four smoothed papyrus columns and screen walls. Beyond the pronaos lies the hypostyle hall covered with decorations dating to Ptolemy III and IV on the south door jamb of the hypostyle all, the top register has the king making offerings to Amun-Re.

The middle register depicts the king offering wine to Mut, and in the bottom register the king makes an offering, perhaps of Ma'at, to Amun-Re. On the north jab, the king offers wine to Amun of Perwesekh (the ancient name of Ghuieta).

After the hypostyle hall is an offering room with a sanctuary. On the north interior wall of the sanctuary are the figures of the god Khonsu (falcon headed with moon crown) and Amun-Re-Min. The make up part of a scene depicting the king making offerings to the triads. The north and south wall of the sanctuary are the only areas in the temple that have plaster and paint decorations.

The remainder of the temple has "simple" raised or sunk bas relief with painted stone.

There is also a chapel of the deified king and side rooms with stairs that lead to the roof. The roof contains areas dedicated to Osiris with some scenes depicting the burial of the god, a feature that was not uncommon in the Graeco-Roman temples.

Many of the temples representations are distinctive, not only for their rather bold style but also for a number of themes such as the catalogue of deities represented in the sanctuary. In the hypostyle hall a winged, blue figure of Seth with a falcon head, who is overcoming the serpent Apaphis with his spear, has been regarded by some art historians as a precursor of the motif of St. George and the dragon.

Graffiti found in the hypostyle hall includes the names of several nineteenth century European travelers, including Cailliaud, who claims to have discovered the temple, Drovetti, Rosingana, Houghton, Hyde, Schweinfurth and Rohlfs. In front of the temple are found Greek and Roman tombs (Ref: http://www.touregypt.net/elkharagatop.htm.).

II.3.A2. Site geologic description

Hibis Temple is located just over two kilometers north of the modern city of Kharga, in the Kharga Oasis depression, between the foothills of Gebel al-Teir and el Nadura in a relatively low land site (Fig.K6). It is surrounded with dense cultivated zones which has low topography (Figs.H1 and H2). To the the south of this cultivated land a vast urban area is located. To the north of Hibis Temple, there are some relatively small hills, which are mainly formed of sandstone with shale and clay intercalations. In the low lands between these hills, variegated shales and clays are exposed and partly covered with sand sheets and sand dunes (Fig.K5*).

Hibis Temple site is bounded with sand dune zones (no direct contact, but a little bit far) from the West and East directions. These sand dunes are following N-S direction. These sand dunes form a hazard on the Hibis Temple site where the winds find a nearby source of sand to carry and take part of erosion effect on the components of this temple.

The presence of Hibis Temple in a low land location which is bounded by dense cultivated land is constructing a real hazard on the temple foundation stability. This hazard is represented by water seepage from irrigation of the dense cultivated lands encircling the temple (Figs: K5* and K6). It is noteworthy to mention some seepage

and water bonds and dense cultivated land are noticed in the near vicinity of Hibis Temple (Figs.H20 to H25)*.

During field study for the monumental sites in El Kharga Oasis, it is found that the bed rock under Hibis Temple is formed of thick clay beds which reach more that 14m thickness. These clays are mainly belonging to the variegated shale units. Six clay samples have been collected from a bore hall drilled in Hibis Temple site. More than 14m of the bed rocks under Hibis Temple are formed mainly of clays (Fig.K7). These samples represent the foundation geologic units under Hibis Temple). It is found that these samples are mainly composed of clay minerals. X- ray diffraction analysis for these samples has been done for the determination of the type of clay minerals (Appendix: Figs.X1a, X1b, X2a and X2b in the Appindex). The types of clay minerals in these samples are presented in table H-1. It is noticed from this table and x-ray analysis that the foundation bed rocks under Hibis Temple are formed mainly of clay beds. The recorded clay minerals are represented by Kaolinite and illite

Kaolinites: They are composed of one tetrahedral sheet linked to an octahedral sheet; therefore they are classified as 1: 1 type layer silicates. The two surfaces of a 1: 1 mineral are formed by different ions: One consists of tetrahedral oxygen and the other of OH^- ions belonging to the octahedral sheet. When the 1: 1 sheets occur in stacks, the OH^- ions of one sheet lie next to and in close contact with the O^{2-} layer of its neighbor. Because of this arrangement, the positive charge of the H^+ ions in the OH^- layer exerts a strong attraction for

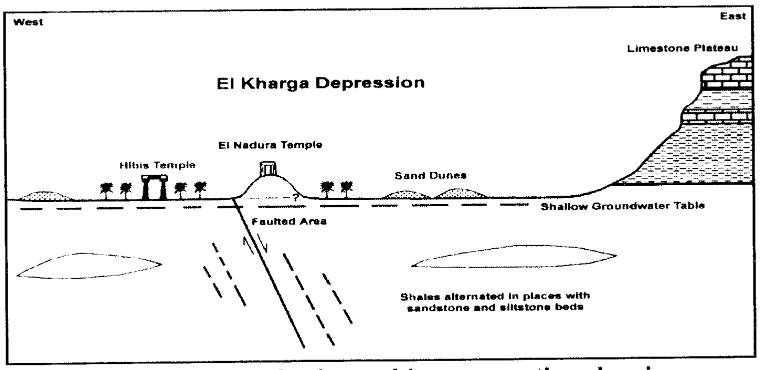


Fig.K6: Geologic and physiographic cross-section showing some of the studied monumental sites at El Kharga Oasis (not to scale).

The negative oxygen of the neighboring sheets. In this way the platelets of kaolinite are tightly bound together. Kaolinite is a non-expanding mineral; hence it is unable to absorb water into the interlayer position. The non-expanding character of kaolinite explains the failure of soils high in this clay to swell or shrink much on wetting and drying. Kaolinite has a basal spacing fixed at 0.72 nm, which is small compared to the other clay minerals (Ref. http://www.soils.wisc.edue/courses/SS325/silicates.htm).

Illites (Hydrous Micas): They are 2: 1 type minerals containing sufficient interlayer K^+ to limit expansion on wetting. The K^+ content of hydrous mica is less than that of micas. Charges not neutralized by K^+ are countered by hydrated cations. Formation of hydrous mica is favored in K-rich sediments. The process of hydrous mica formation is initiated as K^+ replaces some of the interlayer cations of montmorillonites or vermiculites, and is completed when heat and pressure cause the dehydration and collapse of the clays into non-expanded forms. Hydrous micas are widespread in soils. The layer thickness of hydrous micas is about 1.0 nm.

The presence of these clay beds as foundation bed under Hibis Temple can be consider as a great hazard which can affect the stability of the temple site. Moreover, the presence of the temple site

in low land within El Kharga Oasis depression adds additional hazard where the water seepage from the surrounding dense cultivated lands is evident (Figs.K6 and H2). So, these geologic and physiographic features should be taken in consideration in the process of restoration of Hibis Temple.

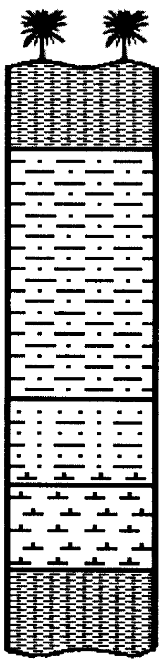
Lithologic log	Thickness (m)	Description
	Ground surface	Deflated peneplained muddy ground surface covered by sand ripples, heaps and sheets.
	2	Light brown sticky clay containing plant roots.
	6	Dark brown wet shale showing high content of organic matter and offensive odor. It shows dark/light brown lamination in the upper part.
	2	Dark brown wet shale with fine sand streaks; becomes marly in the lower part.
	2	Dark brown wet marl with offensive odor.
	Bottom	Dark brown wet clay with dark spots of fermented organic matter.

Fig. K7: Lithologic log of the drilled borehole at Hibis Temple site

Table H-1: Lithologic description for the samples collected from drilled bore hall in Hebis Temple site showing the type of clay minerals

No.	Depth (m)	Lithologic description	Clay minerals
2	0.00-2.00	Light brown clay, steaky containing plant roots	Kaolinite and illite
4	2.00-4.00	Dark brown wet laminated clay, lamina alternate between light brown to dark , offensive odor	Kaolinite and illite
6	4.00-6.00	Dark light brown clay, hard containing organic dark spots	Kaolinite and illite
8	6.00-8-00	Dark light brown clay, hard containing organic dark spots	Kaolinite and illite
10	8.00-10.00	Dark clay, wet, containing fine sand streaks turning to marl at the bottom	Kaolinite and illite
12	10.00-12.00	Dark brown marly clay	Kaolinite and illite

II.3.A3. Hazards on Hibis Temple site

Based on the field observations and the geologic studies for the site of Hibis Temple, some remarkable destructive hazards can affect this archaeo-logical site. These hazards are represented by the following factors:

- Soil defects and ground water [*The main destructive factor of Hibis Temple*]
- The effect of micro-biology
- Wind erosion
- Man made deterioration
- Bad restoration
- Geological defect of sandstone

In addition to the damaged of the colour materials of the wall paintings that, used in the temple of Hibis and geological defect of sandstone as building units and weakness of lime mortar.

Conservation study deals with the current status of Temple of Hibis in order to define the suitable way for restoration and protection.

Soil and ground water defects

The choosing of the suitable soil was considered as a very important step in the building construction process. Because of any defect in the choosing of suitable soil for foundation without knowledge of its properties and behavior, soil will be exposed the building to fall down. Also this defect in choosing good soil could be the source of errors for example:

- Using unsuitable foundation with errors in design and materials.
- Error in choosing foundation level.
- Making foundation above unsuitable soil such as fill or clay soil.

That error can be observed in Hibis Temple, which, were founded on unstable soil. It is found that the bed rock under Hibis Temple is formed of thick clay beds which reach more that 14m thickness (Fig. K7).

This temple suffers from the failure of foundations settlement and many cracks in different place of the temple are recorded during this study (Figs.H3 to H6).

Continuous rise of ground water level has been noticed in Egypt in the last two decades. The rise is mainly caused by surface shallow ground water from leaking water supply and sewage systems. Several monuments and historical buildings in Egypt suffer from the effect of ground water mosques, churches, synagogue, fortresses, palaces, tombs, walls, and gates are the usual type of buildings to be restored and which are affected by ground water. The rise of the ground water in many regions of Egypt caused serious problems to Pharaoh [Sphinx for example] Coptic and Islamic Monuments. In some monument's flooring is lower than the surrounding areas. For monuments having the flooring higher than the surrounding street, basements and surrounding trenches maybe permanently flooded. Humid flooring and walls, deteriorated stone wall are usual effects of the near or above flooring ground water influence. Capillary water infiltrates through walls and columns and when this water evaporates, salts are left noticeably on the outer surface of the building elements, deteriorating of the wall and mural paintings.

It is noticed during field work that Hibis Temple site is located in relatively low land and some water ponds are formed nearby of the site (Figs. K5*, K6, H1 and H2). This water pond and other seepage water from surrounding cultivation land can form a real hazard on this Temple. In fact this factor play an important role in the failure happened in Hibis Temple.

Salt effect "efflorescence"

The term "efflorescence "refers to the crystals which grow on the masonry surface. Efflorescence is a deposit of water soluble salts formed on the surface or in the pores of masonry, (particularly certain types of clay brickwork). It is usually visible as loose white powder or as feathery crystals. Occasionally, it appears as a hard glossy deposit covering and penetrating the unit faces. Efflorescence can occur on internal surfaces, as well as, external surfaces and it is often a mixture of different deposits Salts can be deposited below the surface of stone in the pores. The force of salt crystallization [growth of crystals] can cause cracking and disintegration of the materials .

Causes of efflorescence

For efflorescence to occur three conditions must prevail in the following order:

1. The masonry must absorb water
2. The masonry must have a source of soluble salt
3. The water containing the soluble salts in solution must be able to evaporate not only through the pores but also on the surface of the wall to leave a deposit of salt

These three conditions were prevailed in Hibis Temple building. The temple absorbed water from the high levels of underground water that contain a lot of soluble salt from soil. In addition, this saline water was able to evaporate due to the high temperature in Al-Kharga site.

The crystallization of soluble salts on the surface is due to the low rate of ventilation, which makes an evaporation rate lower than the rate of replenishment of water by capillary migration from inside the wall. The salt crystals are formed mainly outside the pores and

consequently the disruptive effect is smaller. When the efflorescence takes place the salt is brought to the surface in solution during the wetting phase, and most of the evaporation from the surface takes place during the drying phase forming salt crystals on the surface(Figs.: R1 and R2).

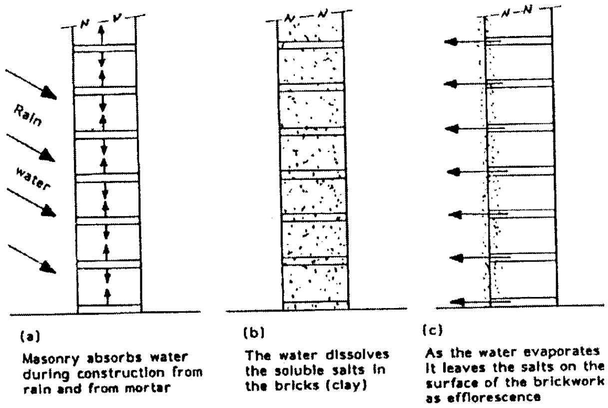


Fig.R1: Causes of efflorescence **a**. **b**. **c** [Thomas 1996]

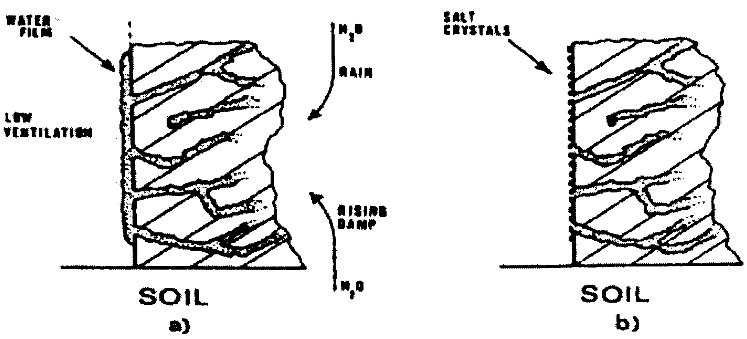


Fig.R2: Evaporation of water on the surface.
(**a**) Wetting phase (**b**) drying phase [Amoroso, 1983]

Salts are deposited internally if the surface evaporation takes place for a relatively short time and most of the evaporation takes place from below the surface. Larger pores are emptied and the liquid front retreats below the surface. i.e. the waterfront is inside the wall. To describe salt crystallization within the pores the experiment carried out by Lewin. [1] It is showed that salt decay occurs only when solute is deposited within the pores of the wall, at a certain distance beneath the external surface in this case: the migration of solution toward the exposed surface is very slow, and crystals will form and grow in the pores, channels, and crevices along the plane at the distance *(d)* below the exterior surface. As these crystals grow, they exert forces on the surrounding bricks. In such situation, the disruptive effect of crystallization is greatest because of limited space. The evaporation surface breaks up quite rapidly. The result is either crumbling of the thin surface layer or the formation of a blister or exfoliation sheet (Figs.: R3 and R4).

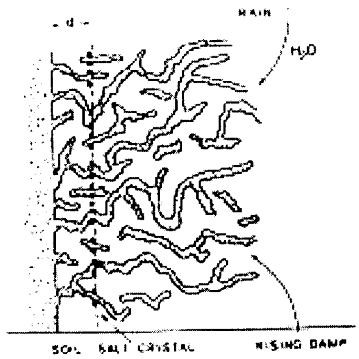


Fig.R3: Sub-efflorescence water evaporates in the pores

[Amoroso, 1983].

1 S.Z. lewin, A. E. Charola, The physical chemistry of deteriorated brick and its impregnation techniques, [in:] Atti del Convegno internazionale Il Mattone di Venezia.,Venice, October 22-23. 1979, pp. 189 - 214.

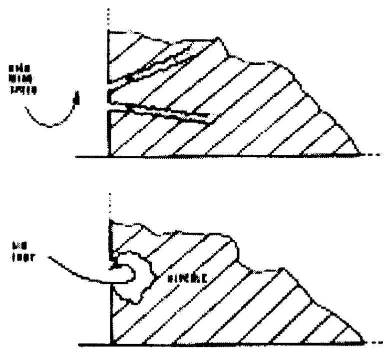


Fig.R4: Water evaporation in the pores leave salt because of salt and wind erosion [Weber and Zinsmesiter, 1990].

A particular type of sub-efflorescence is alveolar type of erosion. This is characterized by the fact that breaking up proceeds preferentially in the same areas, forming deeper cavities [or alveolus], while nearby surfaces may be unaffected.

This process is going frequently on surfaces exposed to strong winds, and evaporation takes place immediately below the surface in the pores. According to Torraca the process undergoes progressive acceleration when a cavity is formed because the wind speed within increases and due to air eddies alveolus erosion is especially common in materials that are not homogeneous. Because the separate components have different physical properties and the evaporation is more rapid in one part than another. Alveolus erosion also sometimes occurs in a homogeneous material

Damages from salt crystallization

One of the most common and extensive sources of bricks deterioration is when salts crystallize in the pores and voids. The visible symptoms of salt deterioration are efflorescence, spalling crust formation, surface erosion [formation of honeycombs], alternatively, increased moisture level in the walls.

Some cases are known, in which the improper application of chemical cleaners also has led to salt deposition on the masonry materials. Capillary action and diffusion processes are responsible for salt migration within the pore system. The site of deposition and the effects thereof can be predicted to some extent. The location is determined by a delicate balance between evaporation of water and re-supply of solution to the site.

The term sub-florescence refers to crystal growth within the masonry material. In an early state of the deterioration process sub-florescence does not cause visible alterations (Figs R5 and R6). This process transports more or less concentrated solutions of salts transported from inner areas of the masonry to the surface. Upon evaporation of water, the dissolved materials [salts] are deposited between the granules, moreover, within the capillaries, and accumulated over the time

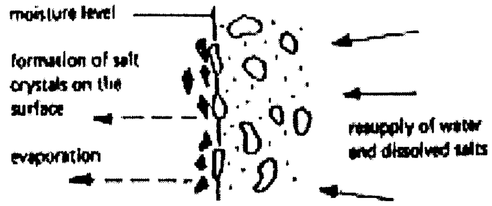


Fig.R5: The formation of salt crystals on the surface, and re- supply of water which dissolved salts [Weber and Zinsmesiter, 1990]

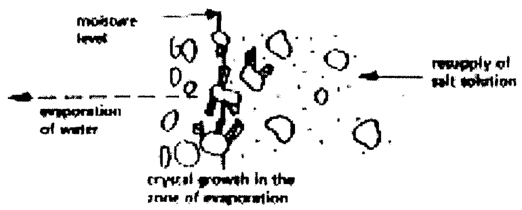


Fig.R6: Crystal growth in the zone of evaporation. [Weber and Zinsmesiter, 1990]

Foundation failures

Foundations can move because of loads applied upon them causing a downward ground movement. Other possible cause of foundation movement known as subsidence is, brought about by activity in the ground, such as:

- Soil erosion caused by flowing water.
- Changes in ground water level.
- Movement due to shrinkage or swelling of clay soils. This is the most common cause of foundation movement.
- Uneven bearing capacities of differing sub-soils.

The above factors have strong impact on Hibis Temple site, so that there are some evidents of movement or settlement. Heave is the upward movement of the ground. It is the result of an increase of moisture [water] content in excess of that, which existed when the building was erected, and it is more dangerous with clay soil, which can be swelling. Heave is also caused by the removal of loads on the foundation by down fall of some parts of the building. Although other possible causes of damage must be considered during the investigation, settlement, subsidence, and heave account for damage to most structural elements, including floors in low-rise buildings. Typical symptoms are: cracks are in external or internal wall. The cracks may be hairline or much wider walls bulging or leaning out of vertical floors slanting out of level, paving cracking and damaging and others (Figs.H1 to H8).

During field study, EGCO working team noticed that the biological deterioration in Hibis Temple is rather severe, especially when it is combined with other weathering processes. The combined effect of these factors constructs a real hazard on the components of this important temple (Figs.H8 to H13). Deterioration due to man mad effects is also noticed in the Hibis Temple (Figs.H14 and H15). This deterioration is rather clear in some reliefs of the temple (Figs.H16 and H17). Consolidate is occasionally show some deterioration in the reliefs of this temple (Figs.H18 and 19).

Fig.H1:The main entrance of Hibis showing some reconstruction work and background cultivation

Fig.H2: Water pond and dense cultivation are nearby causing hazard on Hibis Temple.

Fig.H3: Warping of outer wall.

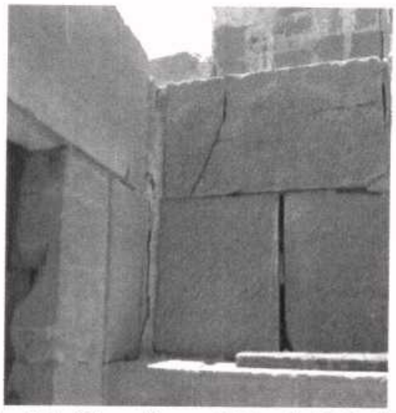


Fig.H4: Shear in wall block (45°-60°)

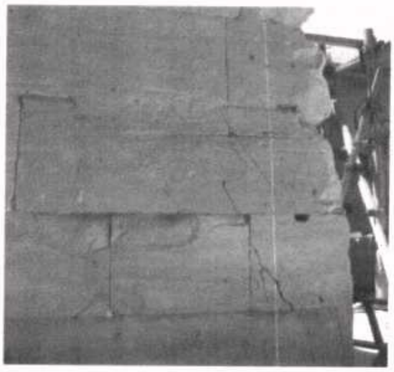


Fig.H5: Shear in wall block (45°-60°), Hibis Temple

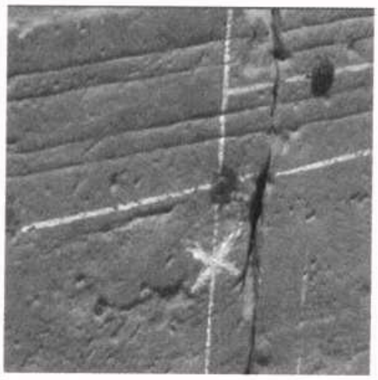


Fig.H6: Fracturing in wall of Hibis Temple

Fig.H7: Deterioration of the columns of the hypo-style hall, Hibis Temple

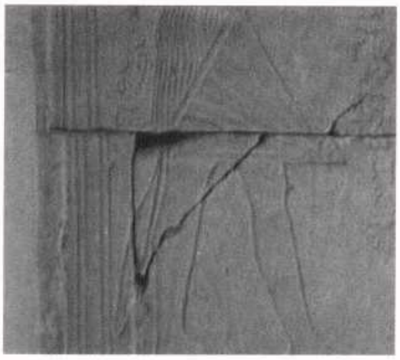


Fig.H8: Deterioration due to fracturing causing relief separation

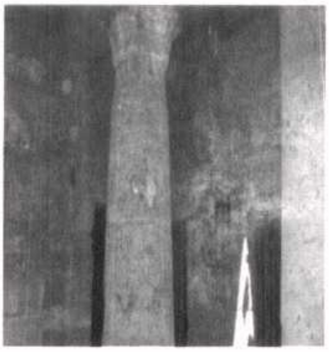


Fig.H8: Bio-deterioration of the column and hall

Fig.H9: Bird's excretion and excavation, main gate

Fig.H10: Stains of bat blood

Fig.H11: Damaged of The main entrance ceiling drawing.

Fig.H12: Deterioration causing loss of ceiling plaster, Hibis Temple

Fig.H13: Bio-deterioration of the column and hall, Hibis Temple

Fig.H14: Man-made deterioration, Hibis Temple

Fig.H15: Man-made deterioration, Hibis Temple

Fig.H16: Deterioration in relief, Hibis Temple

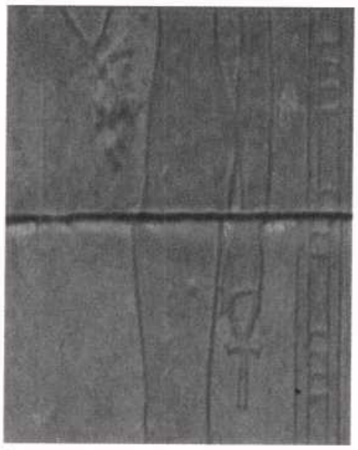


Fig.H17: Displacement of relief, Hibis Temple

Fig.H18: Effect of consolidate (Polaroid B-72).

Fig.H19: Effect of consolidate (Polaroid B-72).

II.3.B.El Nadura Temple site

II.3.B1. Introduction

The temple of Nadura (Fig.NR1) is located just a little over a mile outside of El Kharga and was built by the Romans either during the rule of Antoninus Pius or Hadrian. The temple is much in ruin, but there are paintings of female musicians playing percussion instruments. The temple may have been dedicated to the spouse of Amun. It doubled as a fortress.

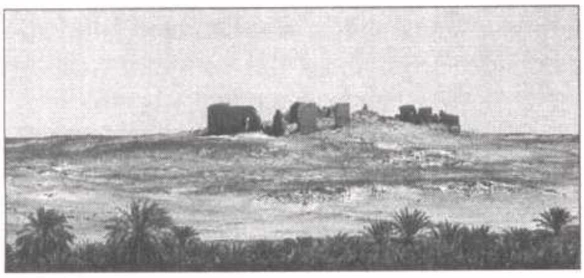


Fig.NR1: General view of Nadura Temple

The temple of Nadurais about 700 years younger than the one at Hibis, and belongs to the 2nd century CE and was built under Roman rulers. Few of Kharga's sights have been so badly treated by time as this, and except for the pieces of the wall, there is little to see here. It is generally attributed to the God Amon, but the few remains of wall decorations represent musicians playing on percussion instruments and sistra. This indicates that a goddess was worshipped here. Near the temple, a semi-troglodyte village lies. The inhabitants built a mud-brick houses, with cellars largely underground. The purpose of this sort of structure, found all over North Africa, was to escape the worst heat in summer time (Ref: http://www.touregypt.net/ elkharagatop.htm.).

II.3.B2. Site geologic description

Lithostratigraphic section was studied in the hilltop monumental site of El Nadura Temple. The mid-depression hills where the monumental sites are founded are composed entirely of sandstone and siltstone beds alternating with variegated shale as illustrated in the

measured lithostratigraphic columnar section in El Nadura Temple (Fig. K10). Some fracturing structures are noticed and measured during field work of this study. The following measurements are recorded: 7°, 10°, 15°, 170°, 173°, 175°, 45°, 50°, 105°, 110°, 135°, 140°, 150°, 160°. These measurements show that the prevailing fracture trends are following in general N-S, NE-SW, NW-SE directions. Most of these fractures are ferruginated and show solution effects (Fig.SD12).

It is note worthy to mention that, it is noticed during field study thatEl Nadura Temple which is located on moderately elevated hill, is surrounded with low lands with some dissected cultivation parts. The temple site is bounded from north and northeast with a huge moving sand dune belt. This dune belt represents the southern continuation of El Maharique sand dune which extends hundreds of kilometers. This dune represents a real sort of hazard on El NaduraTempe and the nearby cultivated lands (Figs. N1 to N6 and N9, N10, N25, N26 and N27).

II.3.B3 Hazards on Nadura Temple Site

Field observations for theNaduraTemple show that different destructive factors are controlling the deterioration of the archaeological site of NaduraTemple. These factors are still threatening the existence of this temple such as:

- Wind erosion, humidity day-night temperature difference.
- Sand dunes hazard
- Man made deterioration
- Defects in building sandstones and bad reconstruction

In addition to the above factors, other factors are represented by the raw materials of mud brick; clay mortar and clay plaster that used in the construction of the outer walls and structures ofEl Nadura Temple and the presence of some defects of sandstone as building units.

Conservation study was deals with the currant status of of NaduraTemple in order to define the suitable way for restoration and protection of NaduraTemple site as follows:

Wind erosion, humidity day-night temperature difference

The wind has been considered as an agent of weathering although this opinion is supported by nothing but the visual observation of some characteristic features in the decayed brick and other structures in the temple.

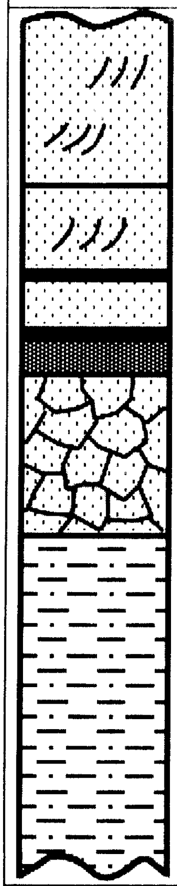
Lithologic log.	Thickness (m)	Description
	Top	Yellowish white cross-bedded sandstone
	4.5	White cross-bedded sandstone
	2.5	Brown to black ferruginous sandstone (0.5m)
		Mottled white to yellowish brown sandstone
	1.5	Variegated green shale (0.5m)
		Brown to black ferruginous sandstone
	8.0	White sandstone becomes ferruginous in joints
	Bedrock	Variegated red shale

Fig.K8: Lithostratigraphic section of El-Nadura Temple hill

The idea is that the wind can carry sand particles and clash them on the historical building. In El Nadura Temple some sand dunes were surrounded the location of Nadura Temple and threaten the temple as gunfire with help of the wind (Figs.N1 to N10).

The mountain - valley wind is a common wind system caused by differential heating. In this case, air tends to flow down the valley at night. Valleys are cooler at higher elevation and the driving force for the air-flow results from the differential cooling. Similarly cool air flows into the valley of the mountain at night. During the daylight hours, an opposite flow may occur as the heated air adjacent to the sun-warmed ground begins to rise and flows both up the valley and up the mountain slopes. However, thermal turbulence may mask the daytime up slope flows, as that is not as strong as the night time down–slope flow. Both the sea breeze and mountain-Valley wind are important as meteorological features are wind erosion and air pollution. El Nadura Temple site in the spring is exposed to hot southern winds, [the so–called Khamsin] often turning into sandstorms. These winds have a big negative impact on the temple and represent a remarkable erosion agent which is rather clear in El Nadura Temple (Figs.N3 to N8).

Sand dunes hazard

The sand dunes represent a real hazard on the monumental sites in El Kharga Oasis. This hazard is treated in details at the hazards affecting this area; however some remarkable hazard of the sand dunes is noticed during field study of El Nadura Temple site (Figs.N2, N9 and N10). Some deterioration is noticed in El Nadura Temple due to some defects in the nature of building stones and the mortars (Figs.N11 and N12).. Some deterioration is also noticed due to man made action as writing some names or scratching the reliefs in some parts of the monuments (Figs.N13 and N14).

Fig. N1: General view of El Nadura Temple, sand dunes in the back ground

Fig. N2: Sand accumulation and sand-wind effect on the outer walls,El Nadura Temple

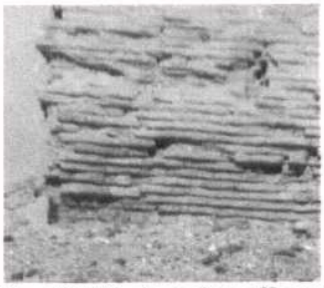


Fig. N3:Wind erosion affected the mud-brick wall, El Nadura Temple

Fig. N4:Close-up view showing the erosion of mud-brick surface, El Nadura Temple

Fig. N5:Wind erosion effect on the sandstone blocks

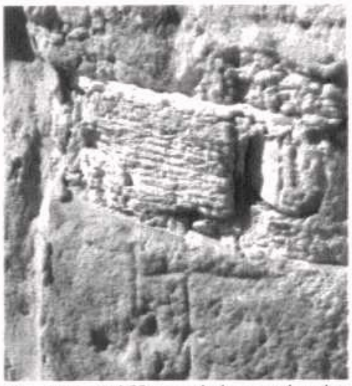


Fig. N6: Differential weathering of sandstone wall blocks

Fig.7:Differential erosion of sandstone wall blocks, El Nadura Temple

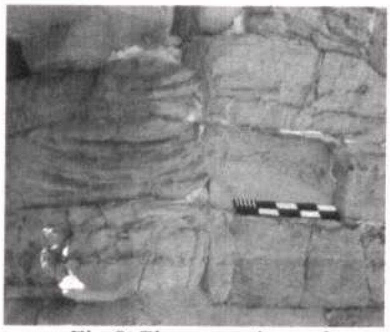


Fig.8:Close-up view of Differential erosion in sandstone blocks

Fig.N9: Sand dunes partly cover the hill slope of El Nadura Temple

Fig.N10: Huge Sand dune belt represent a real hazard on El Nadura Temple

Fig. N11: Cracks in wall blocks and mortar.

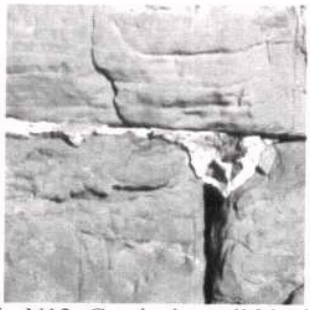


Fig.N12: Cracks in wall blocks and mortar.

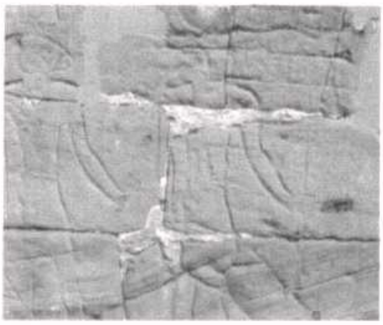


Fig.N13: Deteriorated mortar in relief sandstone wall blocks.

Fig.N14: Man-made deterioration.

II.3.C.El Bagwat site (Christian Ruins in the Kharga Oasis)

II.3.C1. Introduction

While Egypt's Eastern Desert is very famous for its several well known Monasteries, including that of Saint Anthony and Saint Paul, Egypt's Western Oasis served both as a remote haven for early Christians and Kharga specifically, as a place where Christian church leaders were sometimes banished when their views were considered to be unacceptable. Today we may find some of Egypt's earliest Christian monuments in the remote regions, and because of the dry climate, often in a decent state of preservation.

The Christian Remains in the Kharga Oasis

Christianity was probably introduced to the Kharga Oasis in the latter half of the 3rd Century or the beginning of the 4th century. There were a number of important, early Christian leaders who were banished to the Kharga Oasis, especially during the 4th and 5th centuries, for a period of years. Saint Athanasius (Fig. BR1) was sent to the Oasis, but it was probably Nestorius who made the largest impact within the local Christian community. However, though tradition links the local Christians to Nestorius, it is likely that it was more of an isolated enclave of Christians that included both Orthodox and many forms of heteordox Christians.

The Council of Ephesus in 431 denounced Nestorius. He had built upon the teachings of Theodore of Mopsuestia (350-428), from north of Antioch, who saw sin as a weakness instead of a disease or tainted will. Nestorius was accused of the heresy that portrayed Christ's death on the cross as only the suffering of his human half. Likewise, Nestorius saw Mary as the Mother of Jesus and not the the Mother of the "Son of God."

Fig. BR1:Saint Athanasius

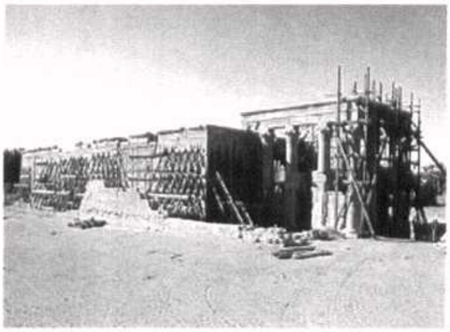


Fig. BR2:The Church in Temple of Hibis

BR3: Drawings in the Chapel of Exodues, El Bagwat

Fig.BR4: The Chapel of Peace, with defaced images of Adam and Eve, the Ark, Abraham and Isaac

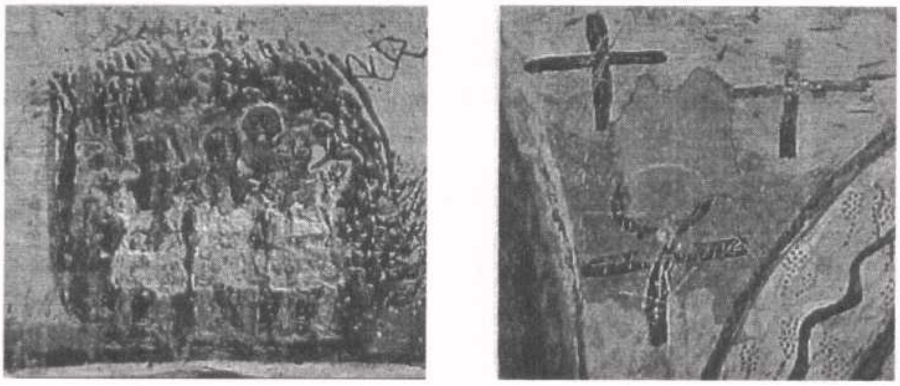


Fig.BR5: Left: Sadrach, Mishach and Abednego in the furnace;
Right: Ankh Style Cross (Ref. http://www.touregypt.net/elkharagatop.htm)

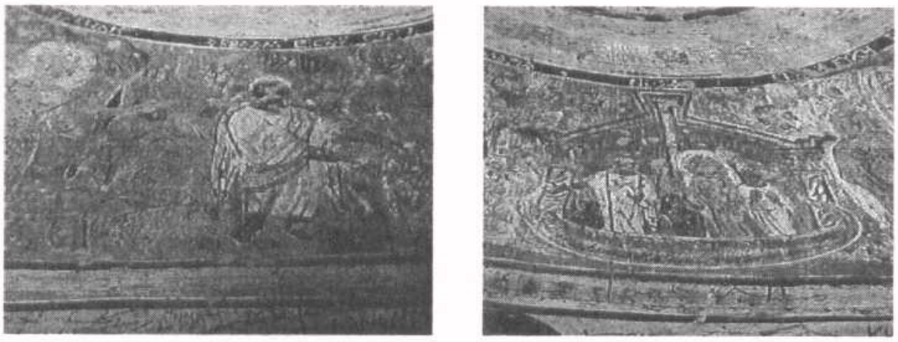


Fig.BR6: Above Left: Abrahham, Right: Noah

He was first exiled to a monastery near Antioch, but that did not silence his teachings. One tradition reported by Moffett was that he was a gifted orator with a "beautiful voice and fluent phrases." He was then banished to Petra (in Jordan) and finally to the Kharga Oasis (in Egypt). Each move took him to deeper isolation (http://www. touregypt.net/elkharagatop.htm).

Near the Necropoliis of El Bagwat is perhaps the best known monument in the Kharga Oasis, the Temple of Hibis (Fig. BR2). Built by Darius I (about 521 BC) and added to by Darius II, it was later restored by Nectanebo (378-60 BC, and represents the only Persian Temple we know of in Egypt.

However, soon after it was abandoned by the pagan priests, a Christian church was erected against the structure's north side of the portico. This probably took place in the first part of the 4th century. Unfortunately, its destruction probably was at the hands of the Blemmyes who invaded Egypt and sacked the temple in about 450 AD. At that time the Blemmyes carried off a large number of prisoners, including Nestorius himself. Within the temple itself, there are only two inscriptions that specifically refer to this ancient church. (http://www.touregypt.net/elkharagatop.htm)

Probably the most significant Christian remains in any of the Western Oasis are those of the Necropolis of al-El Bagwat in the Kharga Oasis, yet these ruins actually predate Christianity and consist of both pagan and Christian Temples, chapels and burials. They date from between the 2nd and 6th centuries. However, this is considered to be one of the earliest and best preserved Christian cemeteries in the world.

The ruins are situated on the slopes of Gabal al-Tayr, about one and a half kilometers from the only known Persian Temple in Egypt, Hibis. The necropolis covers an area of about five hundred meters in length and two hundred meters wide. The main entrance to al-El Bagwat is at the south side. There are some 263 chapels or shrines located in the necropolis that have been built in eight distinguishable groups.

The Main Church

In the center of the Necropolis on the northern edge is a church dating back to the 5th century AD. It is regarded as one of the oldest churches in Egypt, and commands a grand view of the necropolis. It is the largest of the structures to be found here.

The Chapel of the Exodues

Situated behind the group of chapels located on the central ridge in the northern part of the necropolis is the Chapel of the Exodues. It may be considered one of the oldest Christian chapels in the necropolis, with paintings attributable to the first half of the fourth

century. Yet, there is very little Christian to be found here, as most of the interior is painted with scenes from the Old Testament. It takes its name from the paintings of Moses leading the Israelites from Egypt, Moses in the Sinai, the Egyptian King and his army, Noah's Ark, Adam and Eve, Daniel in the lion's den, Sadrach, Mishach, and Abednego in the furnace; the sacrifices of Abraham, Jonah in the whale, Jonah out of the whale, Rebeca at the well, Job in a chair, Job suffering, Susanna and Jeremian at the temple, Sara in prayer, a shepherd, the martyrdom of Saint Thekla, seven virgins, and the Garden of Eden. Only a few scenes touch upon Christian topics.

The Chapel of Peace

On the western slope of the necropolis, near its entrance, is found the Chapel of Peace. It stands alone, and is often simply referred to as the Byzantine Tomb. Its walls are covered in Arabic, Coptic and Greek graffiti, while the formal decorations are of a pure Byzantine style. Identified in Greek are the names: Adam, Eve, Abraham, Issac, Eirene, Daniel, Dikaiosyne, Euche, Jacob, Noah, the Annunciation of the Virgin Mary, and Paul instructing Saint Thekla. The decorative theme (Figs.BR3 to BR6) is very similar to those found in Rome at the catacombs and in many early churches throughout Egypt and elsewhere.

They may probably be attributed to the 5th and 6th centuries. One typical Egyptian scene within this chapel is a portrayal of Saints Paul and Thecla, who seem to have been very popular saints within this oasis. Also within the necropolis are about five other chapels that still have the remains of good paintings, including themes such as Saints Paul and Thecla, the Sacrifice of Abraham and the Phoenix.

Interiors of El Bagwat

Most of the interiors of the chapels of El Bagwat were probably without much decoration. And among the ones which were decorated, the hardship of time has been cruel. In the finest, the figures have been defaced by Muslim fanatics decades ago.... and the walls of the interior are decorated with biblical scenes. The best of these is the Chapel of the Exodues, showing scenes from the Jews and Moses escaping from Egyptian

troops. The Necropolis of El Bagwat is a reminder of one of the most central battles of early Christianity; the dispute over the nature of Jesus. The 5th century bishop Nestorius was exiled to El Bagwat (as the village was called) for having claimed that only one of Jesus' natures had suffered on the cross; the earthly nature, not the divine. The large extent of the Necropolis of El Bagwat is the result of the, his and his supporters' exile. The tombs here are believed to indicate that worship of the dead was continued in a Christian style. There are 263 mud-brick chapels climbing up a ridge, the oldest dating back two centuries before Nestorius, the last dating back to the 7th century.

II.3.C2. Site geologic description

El Bagwat Cemetery is located at about 3km to the north of the center of El-Kharga town and about 1km to the north of Hibis Temple. It is constructed on smooth relief hell which is composed mainly of sandstone and clay – shale beds intercalations. The geologic nature of this fault-affected site, which comprises several black shale, northward-dipping cuestas capped by sandstone beds, could nominate this site to be used for these purposes.

El Bagwat Cemetery comprises about 263 tombs (mostly dating from the 4th through 6th centuries, AD) in the pattern of domed chambers, as well as 120 Nestorian chapels where the dead could be worshipped. Some of the tombs have paintings of biblical scenes. In the center is a church dating back to the 11th century AD. It is regarded as one of the oldest churches in Egypt.

Lithostratigraphic section was studied in the hilltop monumental site of El Bagwat Cemetery. The mid-depression hills where the monumental sites are founded are composed entirely of sandstone and siltstone beds alternating with variegated shale as illustrated in the following lithostratigraphic columnar section in El Bagwat Cemetery (Fig.K9). Some fracture structures have recorded during the field study of the present work. These fractures follow 0°, 10°, 30°, 40°, 50°, 105°, 140°. So, the main prevailing fracture trends are N-S, NE-SW, NW-SE and WNW-ESE directions, which are often concordant with the faulting structure in the area. Cross bedding structure is frequently noticed in the sandstone beds of El Bagwat Cemetery (Fig. B2).

El Bagwat Cemetery was constructed from mud brick chapels with domed roofs in most cases (Figs.B3 to B4) on a small hill which is surrounded with some cultivated land. They were probably built over the site of an earlier Egyptian necropolis of pit-graves or rock-cut tombs. Some of the more interesting structures located here include the Chapel of Peace, with paintings of the apostles, the Chapel of Exodues, with better preserved pictures, and old Testament biblical stories, and the Chapel of the Grapes, with paintings of grapevines

It is also noticed that El Bagwat Cemetery was constructed on more than one ground level according to the nature of the geologic unites. This fault-affected site comprises several varicolored clay beds dipping northward and intercalated with cross bedded sandstone thick beds So, the slope of this hilly site shows step like form due to differential weathering of sandstone and shale beds (Figs.B1 to B6).. This geologic nature could nominate this site to be used

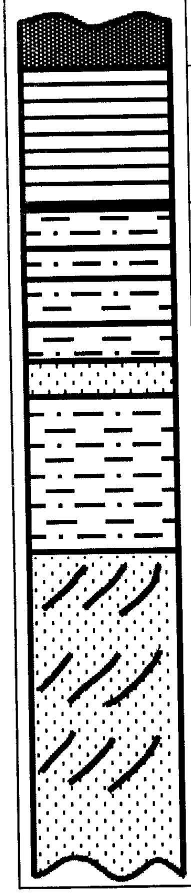
Lithologic log	Thickness(m)	Description
	Top	Blackish sandstone with iron concretion
	7.0	Black shales
	8.2	Variegated green to black shales intercalated with thin ferruginous sandstone thin layers
	1.5	Soft yellowish white sandstone
	8.0	Variegated green to black shales
	Bedrock	White cross-bedded sandstone intercalated with green shale laminae

Fig.K9: Lithostratigraphic section of El Bagwat Cemetery hill.

for these purposes and often controlled the mode of their distribution in the site.

Fig.B1 Gypsum vein in clay beds, El Bagwat Cemetery, El Kharga Oasis

Fig. B2: cross bedded sandstone beds, El Bagwat Cemetery, El Kharga Oasis

Fig.B3: General view shows that El Bagwat Cemetery were constructed on more than one ground level, El Kharga Oasis

Fig.B4:Some of the tombs have courtyards, possibly used for ceremonies, El Bagwat Cemetery

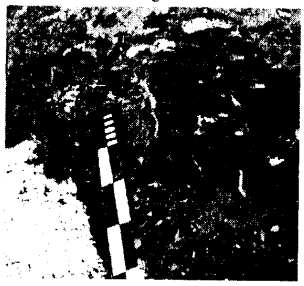


Fig.B5: Shows bed rock of varicolored shale which forming one of the main bed rock units at El-BagwatCemetery

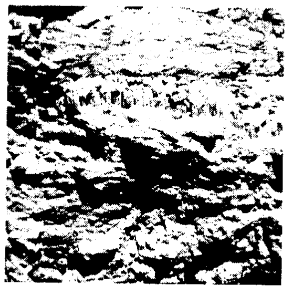


Fig.B6: Shows bed rock of shale with lenticular gypsum band, El-BagwatCemetery

The shale and clay beds are of varicolored; grey, red and light brown, they occasionally include gypsum in the form of patches, veinlets and lenticular beds. They are highly fractured and crushed (Figs.B5 and B6). The sandstone beds are of light brown color, medium hard, highly cross bedded and fractured (Fig.B2). These sandstones are partly ferruginated and silicified especially along some bedding planes.

II.3.C3 Hazards in the Necropolis of El Bagawat

Field observations for the Necropolis of El Bagwat show different destructive factors attacked the archaeological site of Necropolis of El Bagwat [*and still threaten the existence of those chapels*] such as:

- Nature of building materials in Necropolis of El Bagwat
- Wind erosion
- Rains
- Biological effects
- Man made deterioration

Nature of building materials in Necropolis of El Bagwat

The most important problem is the weakness of the raw materials of mud brick; clay mortar and clay plaster that used in the construction of Necropolis of El Bagwat. Conservation study was deals with the currant status of Necropolis of El Bagwat in order to define the suitable way for restoration and protection of the Necropolis of El Bagwat site as follows:

Clay adobe, brick

Clay minerals

Clays are minerals formed by atmospheric weathering of several types of rock. The main components are silicon oxide (also called silica, Si02) and aluminum oxide (also called alumina, Al03).

Clay crystals (Fig.BR1) are very small in size (below 2 microns) and often have an approximately hexagonal shape.

Fig.BR1:Clay crystals and wafer

In the most common clays (e.g. Montmorillonite or Illite) the wafer is composed of two layers of silica and one layer of alumina interposed between them (Fig.BR2).

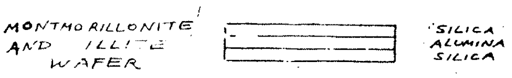


Fig.BR2: Montmorillonite and illite Wafer

The wafers carry hydroxyl (-OH)"groups (Fig.BR3) and negative charges; due to the presence of impurities (e.g. iron) which are able to take the place of silicon and aluminum even if they have less positive charges, (Iron causes the yellow or red colour of fired clay, and the green colour of molten clay.)

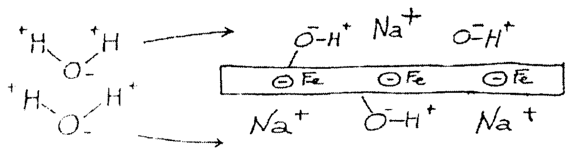


Fig.BR3: Hydroxyl group and impurities in clay minerals

As a consequence, positive ions, like sodium in Montmorillonite, are frequently trapped between wafers and water is able to penetrate--.the crystal as it is attracted by the hydroxyl groups (Fig.BR4).

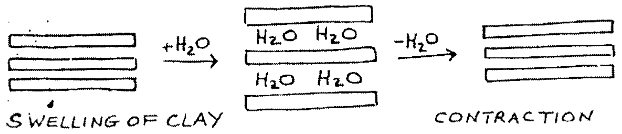


Fig.BR4: Swelling and contraction of clay minerals

The access of water results in the increase of the distance between. Waters and so in the swelling of the clay. In a dry atmosphere the water is lost and the clay undergoes a contraction. Illite contains calcium between wafers and this ensures a stronger attraction between them. The swelling of Illite is, therefore, smaller; Kaolin is very pure clay which contains no iron and has a two-layer wafer; one of silica and one of alumina (Fig.BR5).

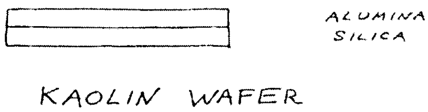


Fig.BR5: Kaoline Waver

As a consequence the wafers have no negative charge and there are no ions trapped between them. The wafers are kept together by relatively strong hydrogen bonds and water is unable to separate them.

A little swelling takes place also in kaolin, however, as water is attracted to the surface of the thin, flat crystals and is able to separate them.

All days are plastic when wet because the thin crystals slide (Fig.BR6) easily over one another under a slight pressure.

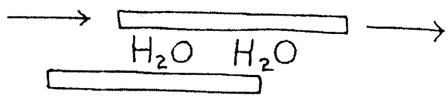


Fig.BR6: Sliding in clay minerals

If more water is added to wet clay it is completely dispersed (Fig.BR7).

Fig.BR7: Water effect on clay

Soil

Soil contains clay minerals and other minerals (feldspar, calcium carbonate, quartz, etc.), that normally have particle sizes larger than clay. Soil constituents are -normally classified by size only, according to the following scheme:

Clay	particle size below 2 microns
Silt	2 microns + 20 microns
Sand	20 microns; 2 millimeters (i.e.2000 microns)
Gravel	above 2 millimeters

A clay-rich soil is plastic and greasy to the-touch; it contracts strongly upon drying and cracks. A sand-rich soil is not plastic, and dry to the touch.

Soil as building material

Clay is the binding material in soil. Frequently its crystals are arranged in a flocculated form that is not very plastic. But if it is left under water for some time the arrangement is changed into a dispersed form that is more plastic (Fig.BR8).

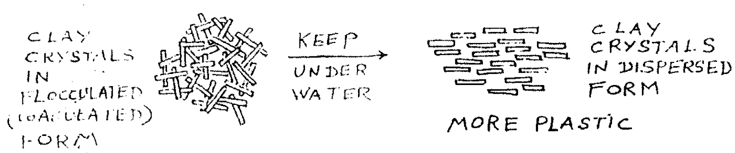


Fig.BR8: Changes in clay due to water effect

The preparation of building materials from the soil always involves a period of storage of the clay-rich soil under water in order to improve plasticity.

Non-clay minerals are useful as inert filler in order to reduce contraction upon drying and so avoid cracking. If necessary (i.e. if the soil is too rich in clay, too greasy) sand is added.

Other possible additions are:

- Fibrous organic materials. Straw or rice husks Animal hair
- Low cost, slightly adhesive, organic materials doing. Fibrous materials improve the tensile strength of the final product that is very low. On the contrary the compressive strength is reasonably high (l0-45 kg / cm2).

Organic -additives may improve the resistance to water introducing a stronger connection between clay wafers and hindering dispersion.

Mud-bricks are' made in square, open bottom, moulds in sizes often around one foot with 6-10 cm thickness. A mortar of similar composition is often used to make up the masonry.

In another type of technology the material is prepared roughly in the shape of spheres that are preserved damp for some time and then placed in position and rammed together to buildup the desired structure. When soil is used to make up, concrete, additions of gravel, stones or potshards are possible.

In building up structures mud-bricks are often coupled with other materials in order to overcome some obvious weaknesses of mud-brick masonry as (Table B1).

Table B1: Coupled Materials with mud-brick structure

Coupled Materials	Reasons
Wood, mats of palm leaves	Where tensile or flexural strength is required. to distribute compressive stress in heavy structures.
Rush ropes	for internal binding of heavy structures
Baked bricks	for weather protection.
Stone	In foundations or water resistant bases of walls.

Normally the surface of mud-brick masonry is covered with a "mud plaster sometimes reinforced by fibrous materials (e.g. hay, straw, rice husks).

Such a plaster weathers out easily and must be frequently repaired (sacrificial protection).

Harder, weather resistant, plasters such as lime or gypsum are also employed. The danger in such cases is that the core material of a wall may be attacked while the surface material resists and so conceals the damage until it is beyond repair. Inspection and maintenance are not easy.

Weathering of Mud-Brick Structures.

The main weathering agent is rain. Excess of water disperses completely the clay and the material is washed away (Fig.BR9). This may happen directly under exceptionally' strong rain, but more frequently, in, an indirect way through the formation of running streams or pools in contact with the masonry.

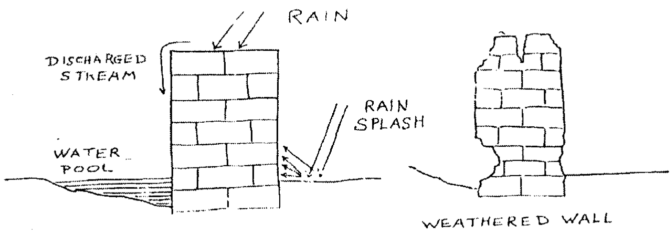


Fig.BR9: Effect of rain water on mud brick

The second weathering agent of importance is wind that acts mainly by sand-blasting.

Capillary rise is low in mud-bricks, contrary to the case of baked bricks; in general is does not surpass 30 - 40 cm. The water content varies slowly with the height of the wall and no humidity front is detectable (Fig.BR10).

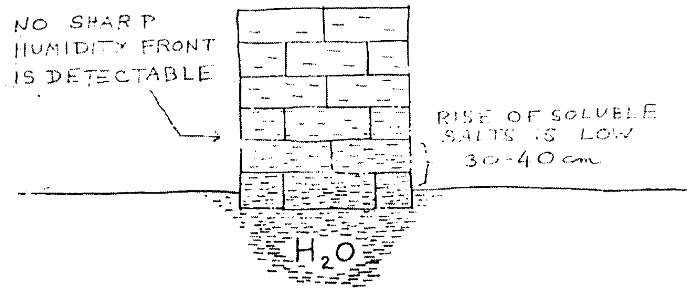


Fig.BR10: Effect of water and humidity on mud brick

Therefore capillary rise and crystallization of soluble salts do not constitute-a major danger for mud-brick masonry except in special cases.

Protection of Mud-Brick Structures
Archaeological Excavations

Mud-brick structures are well preserved when buried in the ground. They must be protected as soon as they are discovered (Fig.BR11).

(a) Total protection - shed

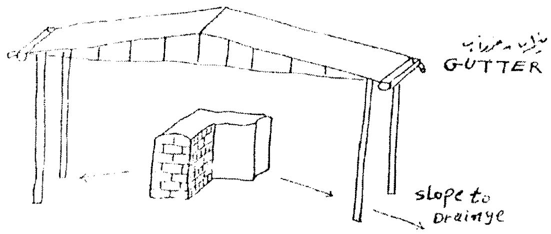


Fig.BR11: Protrction of Mud-brick structures

Formation of water pools near the walls must be avoided providing suitable slopes and drainage systems.

(b) Total protection - Re - burial.
(c) Partial protection

(i) Capping and repairs made in soil-cement.
(ii) Surviving plaster consolidated with adhesives (e.g. polyvinyl acetate emulsions).
(iii) Drainage of rainwater provided.
(iv) Treatment of vertical surfaces (only) with ethyl silicate.

Soil-Cement

Clay – rich soil	8 parts (volume)
Sand	1 part
Portland Cement	1 part
Straw (chopped short)	
Water	

The clayey soil must be left under water a few days; the other components are then added. If soil-cement is used in the form of bricks these are molded in open-bottom moulds and kept damp for one week to allow the cement to set. They are then left to dry in the sun.

Soil-Cement may also be used as stucco for minor repairs or a thin capping layer (Fig.BR12).

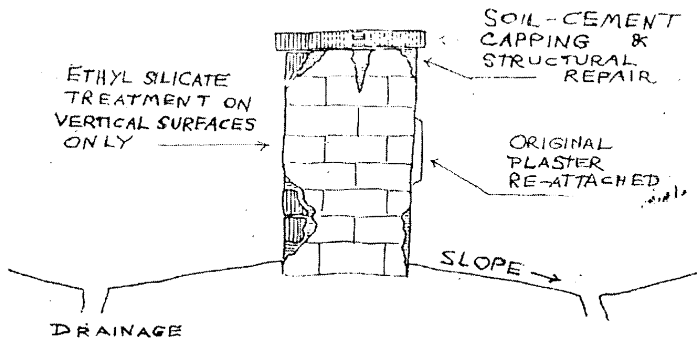


Fig.BR12: Protection of mud-brick structures

Disposal of rainwater must be carefully studied and adequate gutters, slopes and drainage channels provided.
silicate Si $(OC_2H_5)_4$ is hydrolyzed by water in the presence of a catalyst (an acid) and forms hydrated silica Si $(OH)_4$ that can bridge the gap between the clay wafers, cross-linking them. The cross-linked clay becomes non-dispersible in water (Fig.BR13).

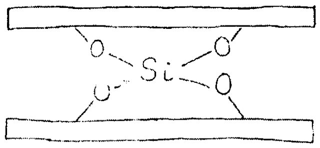


Fig.BR13: Clay wafers cross link

Structures above Soil Level

Buildings built in mud-brick may survive only if subject to continuous maintenance. The key points for maintenance are:
Roofs, rainwater disposal systems, plasters (to be renewed frequently) and bases of walls (damaged by rain splashing or rising damp).

Any shear stress caused by settlement of structures results in cracks due to the weak tensile strength of the materials. Such cracks are extremely dangerous if water is allowed to enter them; immediate repairs are therefore required.

Ruins in mud-brick must be protected by re-forming over them

a roof and a water disposal system. As an alternative proposition, the partial protection suggested for archaeological excavations may also be adopted. In addition to the type of building materials, the other remarkable hazards are represented by: wind erosion, Rains, Biological effects and man made deterioration. These hazards factors are studied in the field by EGCO teamwork and presented as follows:

1. Wind erosion (Figs.B7 and B8) 2. Rains (Figs. B9 to B14)
3. Biological effects (Figs.B15 to B20), 4. Man made deterioration (Figs. B21 to B22)

It is noteworthy to mention that the humidity and air pollution are also common factors for deterioration in El Bagawat site (Figs.B23 and B24). Also, the presence of weak foundation soil as clay associated with gypsum bedded lenses construct an important hazed in this site (Figs.B25 and B26).

Wind erosion

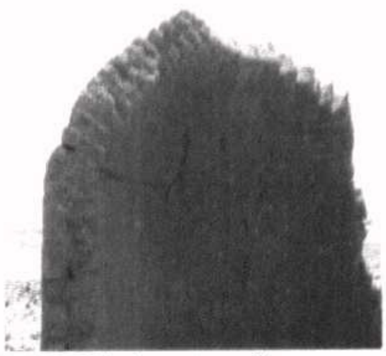


Fig.B7: Wind erosion effects on mud brick ruins, El Bagwat chapel.

Fig.B8: Wind erosion effect and separation of an architectural detail, El Bagwat chapel.

Rains

Fig. B9: The dissolved parts in the main elevation of the chapel due to water rain

Fig. B10: Width of dissolved part 14-18 cm, in normal case and 38-61cm in the other part.

Fig. B11: Outside dissolved mud-brick

Fig. B12: inside dissolved mud-plaster

Fig. B13: The liquefy of mud-plaster and mud brick due to rains

Fig. B14: Outside dissolved mud-brick

Biological effect

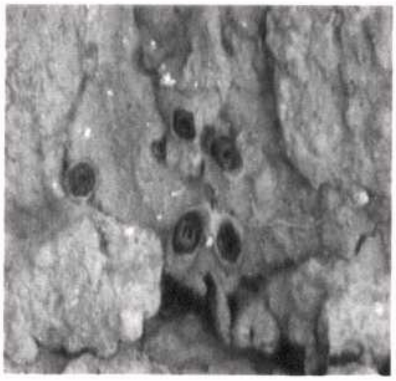


Fig. B15: The petrification Larva of hornet on mud-bricks

Fig. B16: Hornet nests inside the chapel.

Fig. B17: Bird's excretion and excavation in the mud brick wall + fractures.

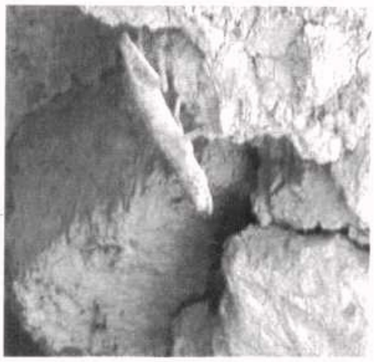


Fig. B18: Chameleon lives on El Bagwat chapel.

Fig. B19:Hornet nests inside the chapel, El Bagwat

Fig. B20:Bio-deterioration on the wall painting of chapel of peace

Man made action

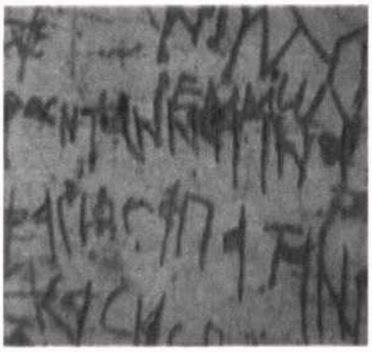


Fig. B21: Man made deterioration inside Chapel of peace

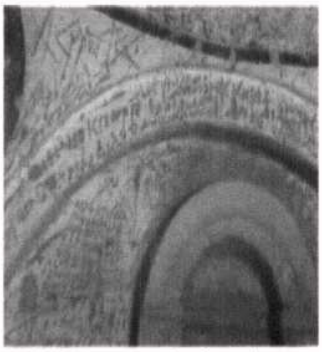


Fig. B22:Man made deterio-rateion inside Chapel of peace

Fig. B23: Deterioration of the the image of Ark "ship of Noah" due to humidity and air pollution, El Bagwat

Fig. B24: Deterioration of the image Abraham and Isaac, due to humidity and air pollution, El Bagwat

Fig. B25: Crack in mud-brick due to unequal settlements and unstable bed rock

Fig. B26: Secondary gypsum veins within clay beds, El Bagwat site

II.3.D. El-Ghueita Temple

II.4.D1. Introduction

About 20 km south of Kharga is the temple Qasr al-Ghweita (Fig.G1) built between 250 and 80 BCE. It was dedicated to the Theban triad Amon, Mut and Khonsu. This temple is constructed on a hill of mild elevation and surrounded with patchy cultivated land; it is in a very ruinous state. It has 10 meter high walls which are still standing and the temple is about as complete as any other popular ancient destination in Egypt (Figs.G1 to G5).

Even large parts of the surrounding village can be seen Qasr El-Ghueita has one of the nicest locations around Kharga Oasis, on top of a circular mountain. Walking up to the temple, it looks impressive and massive, which probably was the intent back in the days of villains and competing tribes.

Around the temple there was a village that must have housed a couple of hundred persons. Some buildings are in about as fine condition considering the age of more than 1,500 years.

II.3.D2. Site geologic description

The fortress of Qasr el-Ghueita is constructed on the top of a sandstone hill from where it commands a strategic view over the desert plain. The hill is composed of variegated shale with some sandy clay and fine grained thin sandstone beds. The site of the temple is surrounded with patchy cultivated desert lands where some locals are living there and cultivate these lands with various types of crops specially dates trees. About 3.5 km to the north of El Ghueita Temple, Gable El Qarn is located. It represents an elongated hill following N-S direction and composed mainly of sandstone-shale intercalations. The low lands surrounding the temple are covered with sand sheets and sand dunes. These dunes and sand sheets partly cover some variegated shale exposures (Figs.K10, K11 and K12).

The sandstones are occasionally cross bedded, graded with mainly light brown color. Remarkable fractures and bed tilting are

obvious in this sandstone. It is obvious that the evolution Gabel El Qarn is due to the major faulting tectonics affected the area through various tectonic cycles. These faults are mainly following N-S trend. Far to the east of the temple site a huge limestone plateau is exposed which forming a great scarp bounding El Kharga depression from the east. The measured fractures in Gabal Qarn sandstone are following 0°, 5° 45°, 50°, 105°, 145°, and 150 ° directions. (N-S, NW-SE and NE-SW prevailing trends).

Fig.G1: El Ghueita Temple, general view

Fig.G2: Main entrance of Qasr El Ghaueita

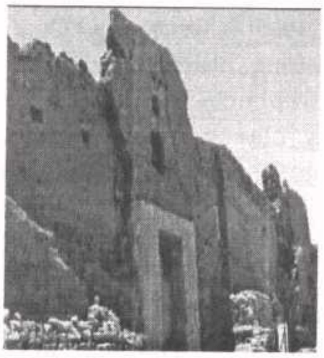


Fig.G3: General view of Qasr El Ghaueita

Fig.G4: The main hall of Qasr El Ghweita

Fig.G5: Mud-brick surrounded the main hall

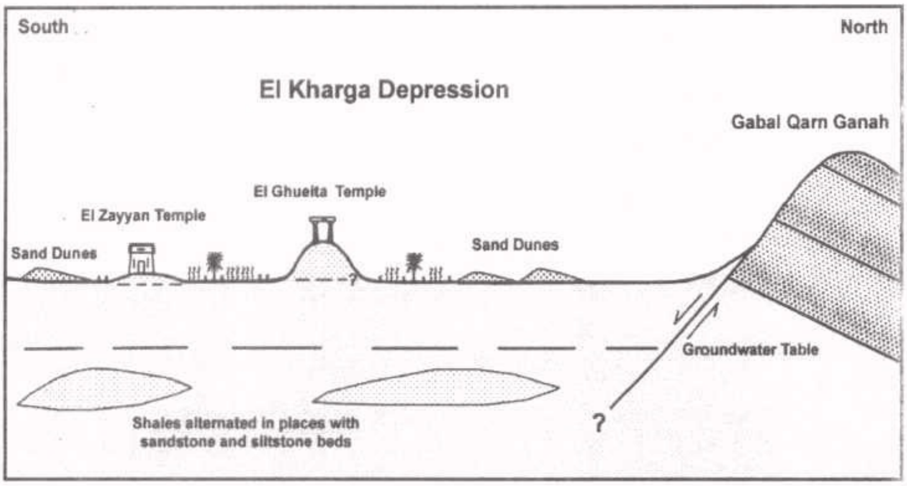


Fig.K11: Geologic and physiographic cross section for El Ghueita and El Zayyan monumental sites, El Kharga Oasis (not to scale).

The temple construction and site selection was very excellent and have been selected on the bases of strategic, geological and geographical bases. The foundation part is covered but it is clear from the surrounding geologic phenomena that it is constructed on one of the sandstone beds which represent intercalations within Variegated Shale unit. It is clear from the deferential weathering notice along the slope of the hill on which the temple was constructed.

It is noteworthy to mention that some of the sandstone blocks from which a part of the temple is constructed are affected with some geologic structural features especially fractures (Figs. G20 to G25).

II.3.D3 Hazards on El-Ghueita Temple Site

After field observation for the Qasr El-Ghueita and first investigation of samples it is showing that different destructive factors were attacked the archaeological site of Al Zayyan Temple [*and still threaten the existence of this Temple*] such as:

- The effect of micro-biology (The main destructive factor Qasr El-Ghueita)
- Wind erosion
- Attacking of sand dunes
- Man made deterioration
- Geological defect of sandstone

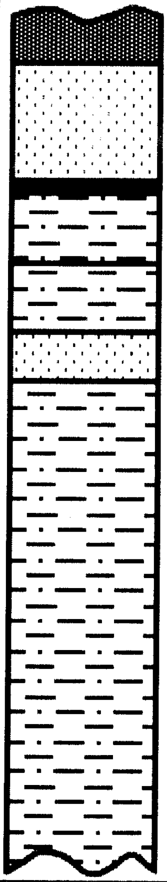
Lithologic log	Thickness (m)	Description
	Top	Yellow ferruginous sandstone
	5.5	Yellow mottled sandstone
		Ferruginous sandstone (0.6m)
	4.0	Green and red shale with sandstone lamina
	4.0	Red shales
	2.0	White soft sandstone
	Bedrock	Grey shales with glauconitic lamina and brown sandstone streaks

Fig.K12: Lithostratigraphic section of Qasr El Ghueita hill.

In addition to the other weathering process and weakness of the raw materials of mud brick, clay mortar and clay plaster that used in the construction the outer walls and architecture details of Qasr el-Ghueita Temple and geological defect of sandstone as building units.

Conservation study was deals with the currant status of Temple of Qasr El-Ghueita in order to define the suitable way for restoration and protection of Qasr El- Ghueita Temple site. Bio-deterioration in the historical building caused by the microorganisms is as danger as the physiochemical processes of deterioration. It can be said that there are some factors controlling the growth of microorganisms on the wall surfaces in the historical buildings this are: the different ratio between humidity and temperatures, sun light, water content in building materials used in these the historical buildings. In addition there are some organic components present in the building.

Deterioration caused by living organisms

Certain plants, fungi, algae, lichens and bacteria have the potential to harm some kinds of stone or stonework. In some cases, the ability to cause serious damage has been well established; in others, it remains conjectural. The process by which deterioration might be caused varies considerably according to the type of organism involved.

Algae

Algae form a group of plants that includes the seaweeds. Freshwater forms, particularly green algae, readily colonize stonework that remains damp for sufficiently long periods of lime. Because they contain chlorophyll, they are able to manufacture most of the food they require by photosynthesis and, under the right conditions, they can multiply rapidly. The green appearance imparted to the stone is often considered to be disfiguring. Studies point that, while the algae alone might not he considered to be too unsightly their appearance is made much worse in an urban environment when dirt readily, becomes entrapped in the algal mass.

Bachmann suggested in 1915 that acidic by products of the algae will attack calcareous stones, hut no quantitative evidence has yet

been cited to show that alga cause any significant increase in the rate of decay of lime stones.

Fungi

Fungi have no ability to manufacture their own food by using the energy of sunlight and hence they cannot live on stone, even if it is permanently wet, unless some organ it' food is present. The waste products of algae and bacteria, or the dead cells of these organisms, can provide such food Decaying leaves and bird droppings are other sources.

Several workers have isolated fungi from decaying stone where nutrients are present. Lepidi and Schippa have found fungal hyphae (the food. seeking threads of a fungus) extensively penetrating the decayed parts of a limestone and apparently burrowing into otherwise sound stone. Fungi can produce organic acids such as oxalic and citric acids. Both of these acids can dissolve calcium carbonate the main constituent of lime stones. Hence fungi are potential contributors to limestone decay. But it has yet to be shown what proportion of the total decay of lime stones is attributable to their activities.

Lichens

Lichens are an intimate association of fungi and algae, in which the fungal hyphae seek the water and salts necessary for both organisms and the algal cells manufacture organic food for both of them by photosynthesis. Thus, it seems likely that lichen are more ~ important contributors to limestone decay than either type of organism on its own. It has yet to ht, demonstrated that their contribution is significant in comparison with the amount of decay caused directly by salt crystallization, acidic gas attack and frost action. This may be because most lichens are killed by even moderate levels of air pollution by sulphur oxides. Studies have reported the rapid colonization of pre-washed asbestos cement of mortar.

Lichens have also been known to attack sandstones and even basalts and granites. The attack appears to be mainly on mica in the granites and Bachmann believed it to be chemical in nature. However, there are also reasons to believe that the damage is often the result of

surface stresses induced when the lichens shrink on drying after remaining wet for long periods. Drying gelatine can attack glass in the same way.

Despite the generally attractive appearance of lichens growing on old stonework and the lack of conclusive evidence that they contribute significantly to stone decay, there is a general feeling among conservation experts that lichens should be removed and the stonework treated to discourage re-infection.

Bacteria

Bacteria are a group of living organisms that are so small that their presence is normally recognized only by the chemical and biological changes that they bring about. Thus, unlike lichens, algae, fungi and higher plants, bacteria do not significantly change the appearance of stone by their presence. If they play a part in the decay of stonework, it b because they initiate or augment the production of chemicals that can attack stone or mortar directly.

As early as 1911 Andersun suggested that bacteria might play this kind of rule. Since then, many biologists have isolated bacteria from decaying stonework and shown that they are species that could almost certainly have contributed to the observed decay, The groups of bacteria most likely to be involved are those that can oxidize sulphur or one of its compounds to form sulphuric acid which attacks limestone directly, those that oxidize ammonia in the air to form nitric acid, which also attacks limestone directly and those that produce organic acids with the power to dissolve silicates However, in nearly all cases, little or no evidence has been produced to show that the decay caused by bacterial products is significant in comparison with the decay caused by salt crystallization frost and the effects of air pollution.

From the practical point of view those concerned with the conservation of stonework need take no more than an academic interest in the matter until it can be shown that the use of some bactericide can significantly decrease the rate of decay of stonework.

During the field work of this study it is found that the main hazards in Qasr El-Ghueita Temple are concentrated in several factors. The biological hazard is treated in the previous pages. This biological hazard is present in many types as represented in the figures herein after (Figs.G6 to G17). The wind erosion hazard is also ofsevereffect on the components of Qasr El-Ghueita Temple (Figs.G18 and G19). The hazard of attaking sand dunes is treated in details at the last part of this study. The hazard of fracturing is also detected in all components of the temple (Figs.20 to G25). This fracture hazard is often due to weakness in the building stones and mud brick, variation in temperature during day and night and weak of foundation soil.

Biological hazard

Fig.G6: Nests in mud bricks

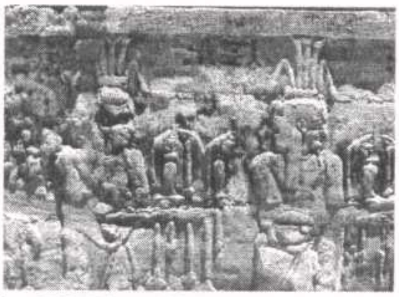


Fig.G7: Bio-effect (deterioration).

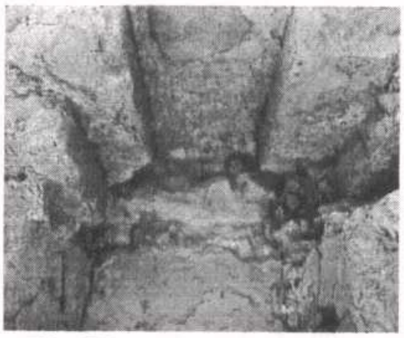


Fig.G8: vault cellar tunnel

Fig.G9: Bio-effect on sandstone and mortar

Fig.G10: Bio-effect in relief figures

Fig.G11: Bio-effect in the roof of the holy of holies.

Fig.G12: Bird's excretion and black layer in the wall.

Fig.G13: Bio-effect in the roof of the holy of holies.

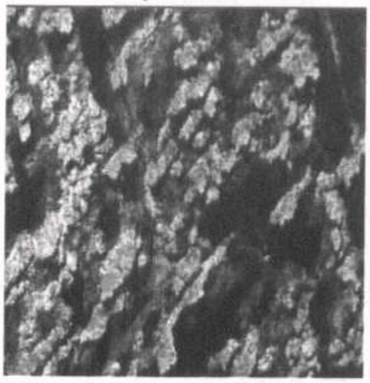


Fig.G14: vault cellar tunnel deposit

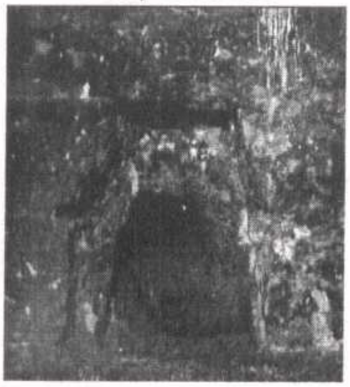
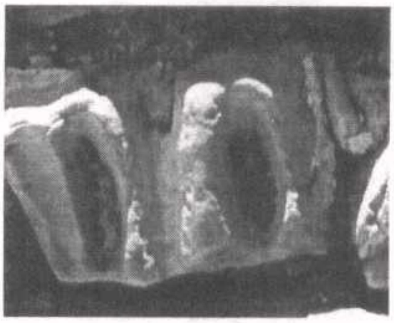


Fig.G15: Hole of rats. Notice degree of deterioration



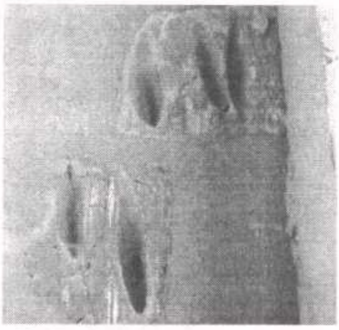


Fig.G16: Hornet nests on sandstone

Fig.G17: Sculpture in sandstone blocks "Honeycomb".

Deferential weathering and erosion

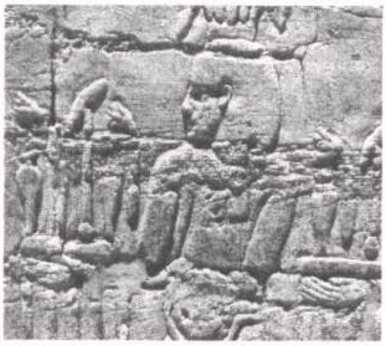
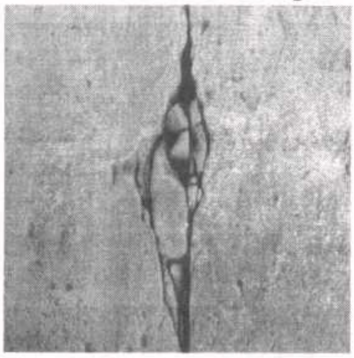


Fig.G18: Differential erosion of mud bricks

Fig.G19: Differential weathering of wall blocks

Fractures and collapse



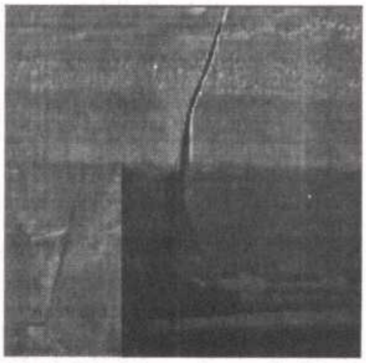


Fig.G20: Fractures in sandstone wall blocks.

Fig.G21: Shear in wall block (45°-60°).

Fig.G22: Shear in wall block (45°-60°).

Fig.G23: Cracks on sandstone relief

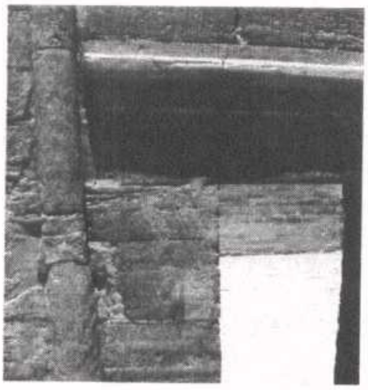


Fig.G24: Shear in wall block (45°-60°) and roof

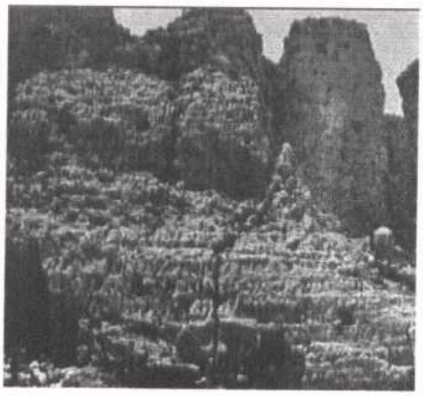


Fig.G25: Cracks on mud-brick wall

II.3.E. Qasr Zayyan Temple site

II.3.E1. Introduction

One of the major monuments of the Kharga Oasis is the Roman (actually of Greek origin) Temple of Qasr al-Zayyan (Qasr el-Zayyan, Qasr Ain el-Zaijan, Qasr Zaiyan), which was and is situated in the ancient village called Takhoneourit, which the Greeks called Tchonemyris.

The town itself is mostly unexcavated, but it was almost certainly of great importance as a major water source during antiquity, and would have been a place where travelers stopped for the night. The remains of the well itself can still be seen close to the mud brick enclosure wall on the western side. There was a major desert route that led from Qasr al-Zayyan to Esna during the Roman Period.

Actually, the temple itself is only a part of a fortress, one of a chain built during this period, with the remaining area being given over to living quarters. It was initially built during the Ptolemaic Period when it was known as the Great Well (Tchonemyris), but was restored and enlarged by the Roman Emperor Antoninus Pius in 138.

The ruins are surrounded by a rectangular mud brick enclosure (actually almost square) wall measuring about 26 meters by 28 meters, Within, this Roman Temple was dedicated to Amun-Hibis, who was know to them as Amenibis. The sandstone Temple was very small when it was first built during the Ptolemaic Period, measuring only about 7.5 by 13.5 meters. The Romans then built a brick hall, some 22 meters long, in front of the main older structure. The temple faces south and can be entered through a sandstone gate erected in the mud brick enclosure wall. On the cage, a dedicatory inscription reads, "To Amenibis the great god of Tchonemyris and to the other gods of the temple, for the eternal preservation of Antoninus Caesar, our Lord and his whole house..." The inscription, dated 11 August 140 AD, goes on to name the governor and other officials involved in the restoration. The main temple building today consists of a court leading to the sanctuary or offering chamber which has an elaborate cult-niche in the north wall, and to an antechamber with a staircase leading to the roof (Figs: Z1 and Z2).

The German geographer, George Schweinfurth, visited the site during the latter part of the 19th century and found potter, coins, and glass and cast bronzes in the area. He recorded that one of the village families kept a bronze as a fertility amulet. Apparently, the local villagers thought that it possessed great powers.

Between 1984 and 1986, the temple went through an extensive

restoration. Also, new excavations were recently begun by the Egyptian Antiquities Organization. They reconstructed parts of the temple, cleared a portion of the interior and discovered kilns, a water cistern and a cache of Roman coins. Other efforts have included a measuring project by a Japanese team from Osaka University.

Fig.Z1: An overall view of the ruins at al-Zayyan

Just below Qasr al-Zayyan, the plain is 18 meters below sea level, the lowest point in the oasis. Here, the cemeteries of the ancient community can also be found.

Fig.Z2: A small pylon gate within the temple of al-Zayyan

II.3.E2. Site geologic description

Qasr al-Zayyan Temple is constructed on low elevated hill (Figs. Z1). The plan surrounding this hill is 18 below sea level, so it forms the lowest part in El Kharga Oasis. The hill is composed of variegated shale with some sandy clay and fine grained thin sandstone beds. The sandstone beds are occasionally ferruginated. It is almost simelar to the succession in El Ghueita site (Fig.K12). The low lands surrounding Qasr Zayyan are covered mainly with quaternary to recent soft sediments as sand sheets, sand dunes and some small sabkha terraces. Moreover, some patchy cultivated lands are also present (Fig. K10').

II.3.E3. Hazards Affecting Qasr Al-Zayyan

After field observation for the Qasr Al-Zayyan and first investigation of samples it is showing that different destructive factors were attacked the archaeological site of Al Zayyan Temple [*and still threaten the existence of this Temple*] such as:

- The effect of birds and bees [*The main destructive factor of Al Zayyan*])
- The huge daily difference between humidity and temperature.
- Wind erosion
- Attacking of sand dunes and sand accumulation
- Man made deterioration
- Geological defect of sandstone

In addition to the other weathering process and weakness of the raw materials of mud brick, clay mortar and clay plaster that used in the construction the outer walls and architecture details of Al Zayyan Temple and geological defect of sandstone as building units.

Conservation study was deals with the currant status of temple of Al Zayyan in order to define the suitable way for restoration and protection of Al Zayyan Temple site.

Birds and bees effect

Small birds can damage soft stone with their bills. The species most commonly involved appear to be the Blue Tit (Parus caeruleus) and the House Sparrow (Passer domesticus) who appear to be seeking grit. They may also be seeking salt. The damage caused by their bills might not be very conspicuous on broad stretches of ashlars, but on carved features in soft stone it can become a matter for concern.

However more damage is unquestionably done by the roosting and nesting of birds on masonry. Starlings (*Sturnus vulgaris*) and wild, feral and domestic pigeons are the main offenders. Decay is caused mainly by the accumulation of their droppings and nesting materials. These can form compost which breaks down as a result of bacterial action and releases acids which will attack limestone and calcareous sandstone. The compost also contains salts which might cause crystallization damage to any susceptible type of stone. This aspect has not been adequately investigated. Such troubles are likely to be most serious when the birds roost among statuary.

Mason bees also can harm stonework. The type involved in bores holes in soft stone to provide a safe refuge for its eggs and grubs. The stones affected are mainly loosely bonded possibly argillaceous sandstones. A massive attack could result in highly disfigured stonework that is possibly so weakened that the stability of that part of the building is threatened. Such attack is however, unlikely to make the stone more susceptible to wind erosion or to any other of the main causes of decay.

The effect of daily difference between humidity and temperature

Stone slabs can he heated on one side so rapidly that parts of their surface will break away from the cooler, underlying mass. Flame-texturing of granite and dense lime-stones depends on this principle. The surface temperature involved is far higher than any likely to be reached by stone exposed to the sun. Nevertheless it is theoretically possible for temperature gradients set up in stone by the heating effect of the sun to lead to surface decay, if repeated often enough.

However a closely related effect is known to cause trouble in marbles. Although marble is essentially composed only of one mineral, calcite, each calcite crystal expands along one crystallographic axis when heated and contracts along the other two. and thus behaves rather like a conglomerate of different minerals when heated, if heated to 300°C and cooled a number of times white, Carrara marble will lose virtually all its strength. It had been founded that a sample of marble, heated to 150°C and cooled a number of times acquired a small permanent set after each cycle and started to bow. The effect is thought to be due to slippage of calcite crystals relative to one another. The bending of marble headstones and marble mantelpieces seems to be due to the same phenomenon.

General considerations suggest that a related effect must occur in granites because its three main constituent quartz, feldspar and mica, have distinctly different coefficients of thermal expansion. On long heating and cooling, there appears to be sufficient micro-cracking at mineral boundaries to make the otherwise resistant granite susceptible to crystallization damage. Studies were carried out many heating and cooling and wetting and drying experiments on granites and concluded that the damaging effects may contribute to the deterioration of granites in monumental structures but that they were probably not the cause of any deterioration of granites in normal buildings

Heating and cooling probably also play an important part in the development of blisters on lime stones once a sulphate skin has formed as a result of attack by sulphur-based gases in the air. The thermal expansion of gypsum is very much greater than that of limestone the ratio is five to one. Thus, it seems reasonable to assume that such differences should lead to a separation of the sulphated layer during heating phase

Wetting and drying is an inevitable part of the process leading to salt crystallization damage to stonework, even if the wetting phase sometimes involves water vapor rather than liquid water. Wetting and drying also accounts for the destruction of slate containing calcite and unstable pyrite. However, the part it plays is a subsidiary one. There

is a widespread belief among building material technologists and geomorphologists that wetting and drying plays a considerable part in causing the decay of porous stone or the disintegration of porous rock. Porous stones expand when wetted and contract on drying. The theory is that fatigue failure must eventually occur, because of the shear forces that will frequently arise along any plane separating the wet from the dry material. This mechanism may account for contour scaling but, apart from this, the decay or disintegration of unconfined stone or rock can not be attributed to wetting and drying alone. One of the more spectacular effects of heating and cooling or wetting and drying is, when a wall of porous material is built under cool, dry conditions between two substantial abutments and its temperature or its moisture content later rises considerably. The attempt of the wall to expand may generate stresses severe enough to cause the masonry to bulge or even to crack diagonally, so that one part can over sail the other. Under extreme weather conditions, the wall will normally be either cold and wet or hot and dry. In consequence thermal movement and wetting and drying movement tend to counteract one another, and little harm is done. Only exceptional hot and wet conditions cause trouble. If the wall is built of virtually pore-free material such slate, only the temperature change will be cant and there can be no off-setting effect. Table 1 gives the thermal and moisture expansions of stone relevant building materials.

Table 1 Approximate thermal and moisture movement of masonry materials

Materials	**Thermal movement 0.000/10°C**	**Dry to wet 0.000/10°C**
Porous lime stones	0.028	0.083
Marble and dense lime stones	0.038	0.000
Granite and other igneous stones	0.100	0.000
Slate	0.110	0.000
Sandstone	0.110	0.670

During field, study numerous deterioration factors are recorded in Qasr El Zayyan site. These deterioration factors represent a real hazard on the temple site. These hazards include; wind erosion and sand accumulation (Figs.Z3 to Z6)*. Another very important deterioration factor is the biological activities in this temple. The main deterioration due to these biological factors is recorded (Figs.Z7 to Z14)*. The fractures represent a real hazard on Qasr El Zayyan site and temple deterioration. Due to these fractures a remarkable deterioration is noticed during the field study (Figs.Z15 to Z18). Most of these hazard factors have a hazard affect on the temple site especially those parts which were built by using the soft mud brick (Figs. Z19 and Z20).

Fractures and temple deterioration

Fig.Z15: The main entrance showing the separated parts between sandstone walls and mud-brick walls

Fig.Z16: A serious fracture affected the outer wall, Qasr Al-Zayyan Temple

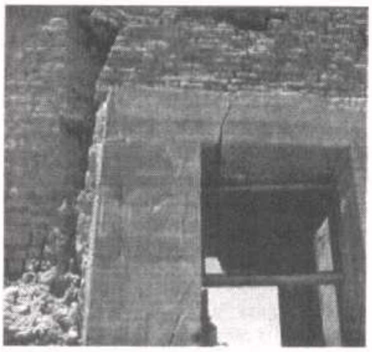


Fig.Z17: Shear stress in lintel blocks (45°-60°).

Fig.Z18: In-situ collapsed wall [decorated elements]

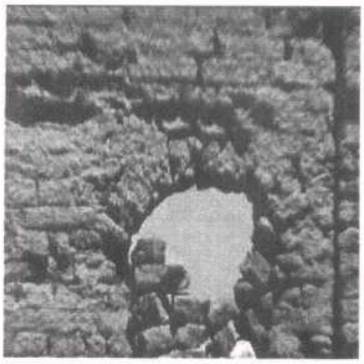


Fig.Z19: Semicircle mud brick arch in a bad condition [architecture details]

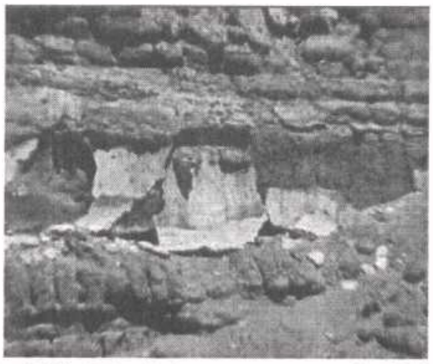


Fig.Z20: The inhomogeneous building materials [Suof plaster & mud brick] were separated

II.4. The Main Hazards Affecting the Monumental Sites in El Kharga Oasis

II.4.1. Sand dunes hazards

The sand dunes represent the most dangerous hazard on the monumental sites in Kharga Oasis area. Sand dunes are best developed along the Kharga depression. Dune belts are oriented parallel to the long axis of the depression coinciding with the direction of the prevailing northerly winds. The spatial distribution of the Kharga sand dunes indicates that they could be grouped into three

belts. The western belt is a continuous belt of simple barchan's dunes and compound barchanoid ridges running from the northern scarp to the south of Abu Bayan area by about 40 km, where it becomes wider and then dispersed into the open desert. The middle belt of barchans is smaller but of great importance due to its hazardous impact on monumental sites, roads and agricultural fields in the cluster of villages arranged longitudinally in the middle part of the depression floor. The eastern belt runs parallel to the north-south oriented eastern scarp. This belt is characterized by barchans, shadow dunes and sand sheets accumulated at favorable sites either on the pediment slopes or on the valley thalwegs where they sometimes cause blockage.

Movement of such dunes is the most serious obstacle for the monumental and cultivated-land areas. Several attempts to avoid dune encroachment have been made by both direct and indirect methods. Dune stabilization by means of vegetation fences, plastic or petroleum spray, vegetation growth or any mechanical means is impractical due to the nature of dune distribution, arid climate and high cost. However, native farmers in the Kharga Oasis usually use fences of palm-leaf stalks to protect their lands due to its higher resistance to sand blasting. In addition, areas of future development should be selected away from baths of dune belts. The sand dunes characteristics and movements in El Kharga Oasis have been treated by some authors; the following is a brief for some important results in their studies.

Ashri (1973) measured the diameters of the sand dunes and their rate of movement at Kharga Oasis, based on two series of aerial photographs more than 16 years apart. He came to a conclusion that the rate of movement of the sand-dunes depends mainly on the size of the dune and the amount of moisture in the surroundings. In his statistical work on barchans sand-dunes of Kharga Oasis, Southern Peru and California, Embabi (1978a) provide that there is a linear relationship and a high degree of association among barchans shape dimensions. He also analyzed quantitatively the dune profiles with respect to slope angle, slope form and dune size. Embabi (1978b) estimates and average annual movement of 100 m for barchans dunes in Kharga Oasis.

Mussa and Farag (1982) studied the Quaternary deposits North Eastern part of Kharga – Dakhla Depression based on aerial photos. They found that sand dunes appear as huge heaps of light toned soft eolian sand; dunes of barchans type and longitudinal dunes trend in parallel orientation in a NNW direction. The Barchans are of different dimensions ranging in length 300-500m and from400 to 700m in width. The height of the dune ranges from 2-20m (Issawi and El Hennawi, 1982). Superimposed barchans indicate local change in wind direction probably represented by eddy current.

The sand sheets are of very low relief, smooth surface, light tone and with no drainage. They are widespread on the floor of the depression especially near dune areas.

Issawi and El Hennawi, (1982) studied the impact of some environ-mental factors on development in Kharga Oasis. They used in this study both aerial photographs and Landsat images and they revealed a soil deflation annual rate between 2 and 2.5 cm. The study also deals with sand movement in the depression. It becomes clear that the dunes are moving southwards by a rate of 30-40 m / year. These two factors indicate that there is a delicate balance between deflation, encroachment of sand moving bodies and the drop of the under-ground water table in Kharga since at least Roman times.

Stokes *et al.*, (1999). Studied the sand dunes in El Kharga Oasis and constructed a map showing sand dunes belt distribution in the studied area. (Fig.K13). It is clear from this map that the sand dunes are of wide distribution in El Kharga area and form a real great hazard on all features including the monumental sites. The hazard effect of this dune belt is extended to the east in the middle part of El Kharga depression where Geble Qarn Ganah is found to the north of Ghaueita and Qasr Zayan Temples. The sands partly cover this relatively high hill. This observation indicates that these dunes have great energy for movements which enable their sands to cover the high hills as will as the low lands (Fig. SD1)*.

Further to the east, the sand dunes are followed, It is noticed that their hazard continue and the old Genah village is completely damage by the dune sands and all the houses are partly or

completely covered with sands and the locals citizens are moved to the New Genah village (Figs: SD2 and SD3)*.

Following to the eastern part of the depression a remarkable dune belt is found, it is more that 10 m elevation (Fig. SD4)*. This dune is bounding El Kharga depression from the east. It partly covers the foot slopes of the escarpment of the huge eastern lime stone plateau which bound El Kharga depression from the east.

The western side of El Kharga depression, the sand dune belt has been followed. It is very huge belt reaches to more than 5 km width and extends tens of kilometers following N-S direction. Sometimes, it shows branches that move toward El Kharga depression (Fig.K13). The study of this sand dune belt near Ganah village, north west of El Ghaueita Temple, shows that this dune belt forms a remarkable hazard on the nearby village and the cultivated lands there (Figs.SD5 and SD6)*.

It is evident from this study that the sand dunes form a real hazard on the monumental sites and some of the development projects in El Kharga Oasis depression (Figs.SD2, and SD3)*. It is evident also that the sand movement rate of this dune is of 30-40 m / year (Issawi and El Hennawi, 1982). The hazard of the moving sands from the huge sand dune belt to the north ofEl Nadura Temple is very clear. In this site some sands derived from the nearby dune belt started to accumulate around the temple and the site hilltop (Figs.SD7 and SD8).

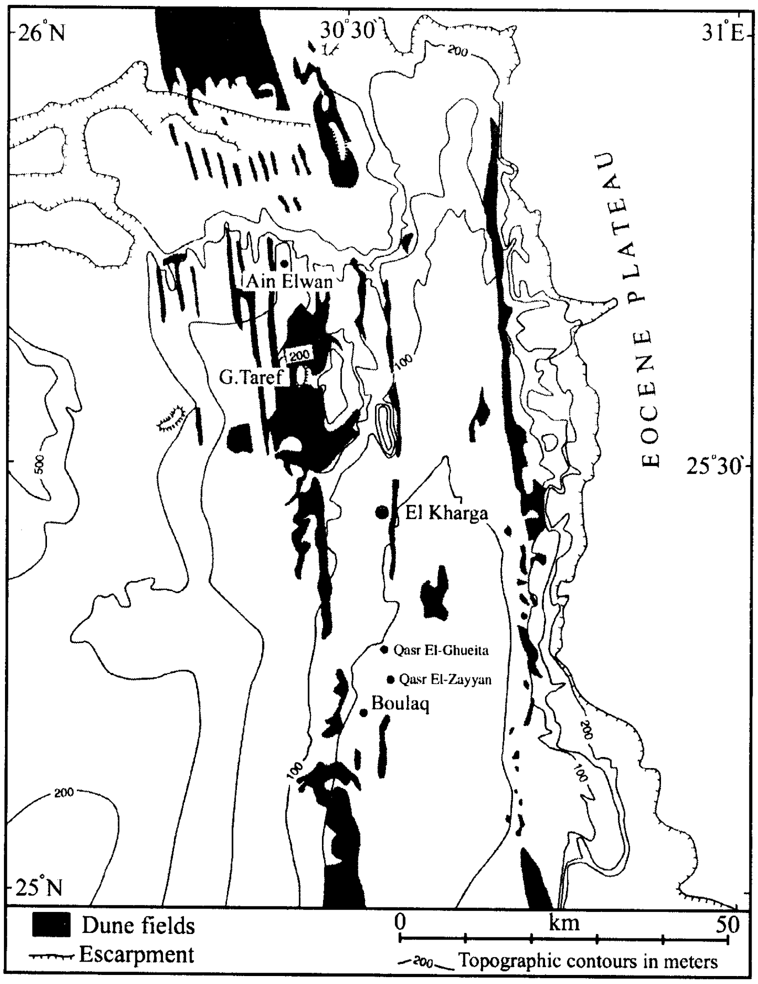


Fig.K13: A Map showing the dune belts distribution at Kharga Oasis (modified after Stokes *et al.*, 1999).

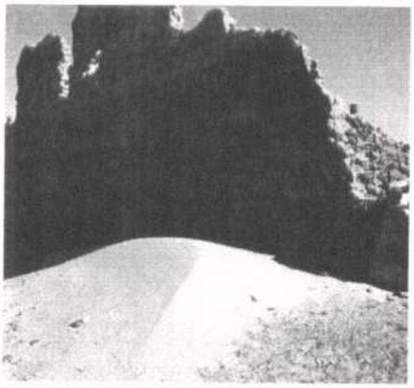


Fig. SD7: Sand accumulation moved from the sand dune belt to the north of El Nadura Temple

Fig.SD8: Huge sand dune belt moving to El NaduraTemple site, Kharga Oasis

II.4.2. Foundation beds and Ground Water Effect

This type of hazard is clear in the site of Hibis Temple and is represent a serious one. In Hibis Temple, the foundation bed is composed from thick succession of clay beds. These clays are formed mainly kaolinite and illite. The presence of Hibis Temple in a topographically lands and surrounded with dense cultivation area (Figs. H20 and H21)* is an additional hazard on Hibis Temple site.

This situation cause water seepage easy to the site of the temple and occasionally forms water ponds in the nearby area of Hibis Temple (Figs.H22 and H24)*. It is noticed that the type of these water ponds are different in acidity-alkalinity nature Figs.H22* to H25)*. The clays under the temple start to swell due to water seepage, which causes numerous disturbances for foundation and the whole structure of the temple.

It is noteworthy to mention the previous investigation studies performed on Hibis Temple site showed that the 10 bore holes drilled in the temple site indicated that the foundation beds are formed mainly of clay beds with high ability for swilling (swilling pressure

equals 3.50 and 6.25 for the studied samples. Moreover, the water level in this site ranges from -5.73 to 8.31 m below ground level (Ismail, et al., 2000).

It can be concluded from our study and the previous works that the water effect and the type of foundation beds in the site of Hibis Temple represent a remarkable hazard.

II.4.3. Biological Effect

During the field investigation carried out during this study it is evident that the biological activities bear remarkable hazard on the monuments in El Kharga Oasis sites. Their damage effects were very clear in the whole studied monumental sites.

Small birds can damage soft stone with their bills. The damage caused by their bills might not be very conspicuous on broad stretches of ashlars, but on carved features in soft stone it can become a matter for concern.

However more damage is unquestionably done by the roosting and nesting of birds on masonry. Deterioration is caused mainly by the accumulation of their droppings and nesting materials. These can form compost which breaks down as a result of bacterial action and releases acids which will attack limestone and calcareous sandstone. The compost also contains salts which might cause crystallization damage to any susceptible type of stone. This aspect has not been adequately investigated...

Mason bees also can harm stonework. The type involved in bores holes in soft stone to provide a safe refuge for its eggs and grubs. The stones affected are mainly loosely bonded possibly argillaceous sandstones. A massive attack could result in highly disfigured stonework that is possibly so weakened that the stability of that part of the building is threatened. Such attack is however, unlikely to make the stone more susceptible to wind erosion or to any other of the main causes of decay.

The following figures can show the bio-deterioration hazard in

the most of the temples in El Kharga Oasis area (Figs.Bio.1, Bio.2, Bio.3 and Bio.4).

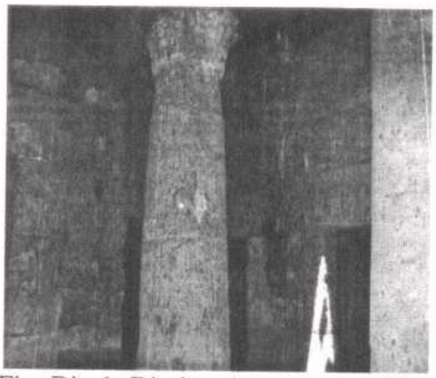


Fig. Bio.1: Biodeterioration in Hibis Temple, El Kharga Oasis

Fig. Bio.2: Biodeterioration in El-Bagwat, El Kharga Oasis

Fig. Bio.3: Biodeterioration in El Bagawat, El Kharga Oasis

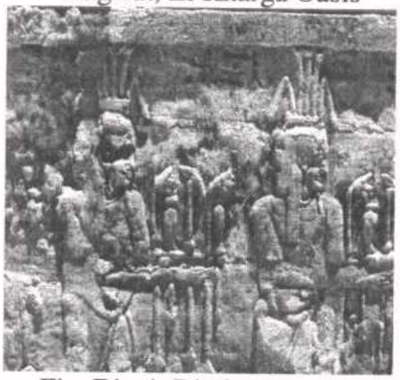


Fig. Bio.4: Biodeterioration in El Ghueita, El Kharga Oasis

Fig. Bio.5: Biodeterioration in El Ghueita, El Kharga Oasis

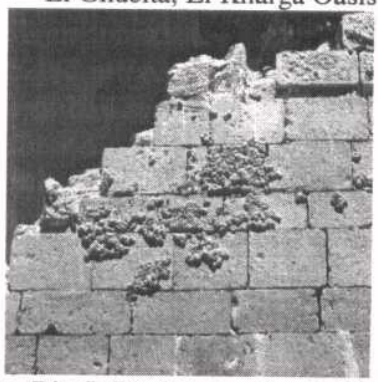


Fig. Bio.5: Biodeterioration in Qasr Zayyan, El Kharga Oasis

Part III. Recommendations

III.1. El Giza Pyramids Plateau

Based on the above study of the geological phenomena in El Giza Pyramids Plateau, it is concluded that the most remarkable hazards affecting this great site are summarized in the following main factors:

*Rocks and foundation bed instability due to the presence of weak zones as a result of faulting and fracturing effects. Some of these faults could be of capable type.

*The presence of karstification phenomenon and caving due to the combined effect of the geologic structural pattern, type of sedimentary rock units, ground water circulation, rains, humidity and surrounding environmental polluting agents.

*The weathering, erosion factors and man made actions represent additional deterioration factors on the monumental complex in this important site.

According to the above detected hazards, the following points are recommended:

1- Accurate fixing and supporting works for the easy slide blocks in the small escarpments nearby Khafre, Mankare pyramids and the fractured zones located at the asphalt road to the north of the Sphinx. Rock bolts with different lengths and diameters are recommended (Dowidar and Abd-Allah, 2001). These bolts will reduce the instability hazard which is represented by rock falls and sliding of blocks at these sites. Moreover, the NW-SE trending fractures which dissect the foundation bed rock of the north eastern of Khufu Pyramid which splay into several branches that enclosed a subsided rhombic-shaped block. The settlement of this block is interpreted as roof collapse of the upper bed over a karsts cavity. It is recommended to use a highly injected impermeable shotcrete to support the zone of plateau between Khufu and Khafre pyramids (Dowidar and Abd-Allah, 2001).

2- An application of suitable geophysical studies to explore the attitudes of the major faults, especially those bearing a northwest trend and caves in El Giza Pyramids monumental complex. This is

rather important to find out the best solution to restore and strengthen the weak zones and to overcome any serious hazard in the future.

3- Recent tectonics study is of prime importance and is strongly recommended. This study is used to determine the association of earthquakes with seismically active structures which can bear a real hazard on some parts of the monumental complex site in El Giza Pyramids Plateau. This study should include investigation about surface faulting potential to identify capable faults. (Salman, 1995), President of EGCO, suggested the following steps for studying surface faults to determine their relationship to recent tectonics:

* Searching for evidences of recent faulting in elevated terraces bed Quaternary sediments nearby the escarpment of the Pyramids Plateau
* Inspecting stream notches in terraces fronts at the intersects with linear trends for profile evidence of faults that offset terrace materials. Also searching should be performed elsewhere in notches for faults that offset terrace caps.
* Searching for evidences of modern faulting in alluvial materials on soil within bed streams in notches features offset roots, bushes, animal trails and man-made features, distorted by faulting should be identified.

If the presence of capable faults is proved, it is necessary to study their chronology. The dating of these faults can be determined by a number of techniques such as structural superposition, stratigraphic superposition and geomorphologic and isotopic dating methods (IAEA, 1979).

It is important to mention that the Great Sphinx is located at the southeastern borders of El Giza Pyramids Plateau. The associated host rocks are represented by marly limestone and marl which are soft and characterized by numerous fractures intersection. Moreover, the Sphinx itself is suffering from fractures influence. In addition to other deterioration factors,

fractures form a real hazard on the Sphinx. If there is any possibility for earthquakes hazard, even with small magnitude, it can dramatically affect this important monument. So, from this point the importance of determination of any nearby capable faults and their relation with earthquakes is very essential.

4- The ground water situation in the Great Sphinx zone should be watched and must be kept in a suitable and safe level. This is rather important, because the under ground water can form a real hazard on the Sphinx site. This is because the Sphinx is located at a lower level at the eastern slope of El Giza Pyramids Plateau and can be subjected to a great hazard due to ground water seepage.

III.2. El Kharga Oasis Monuments

Based on the present study of the geological phenomena in El Kharga Oasis monumental sites, it is found that the most remarkable hazards affecting the monumental sites are summarized in the following main factors:

*Ground water; the ground water effect is rather clear in the site of Hibis Temple due to its presence in a relatively low geographic level in El Kharga Oasis Depression. The source of the ground is mainly from the irrigation water used for the dense cultivated nearby areas. The rains are scarce in this area, however, they form some hazard on the monuments contains mud brick structures like El Bagawat, El Ghueita and Qasr Zayyan sites.

*Sand dunes form a real hazard on most of the monumental sites. It is found that these dunes are moving fast and partly accumulate nearby some monumental sites and completely destroy some relatively recent villages and some cultivated lands. Moreover, these dunes represent a near source for sandy winds storms which make wind erosions very effective in these sites.

*Another important hazard factor is the biological action of birds and other minute organisms. Moreover, the man made deterioration factor is not uncommon.

According to the above detected hazards, the following points are recommended:

1- The ground water situation in the site of Hibis Temple should be watched and must be kept in a suitable and safe level. This is rather important, because the ground water can form a real hazard on the foundation bed of this temple. The water source should be blocked by constructing some isolating barriers on the bases of correct study for the ground water and seepage conditions. De-watering of the soil under the temple is recommended, but this should be based on scientific bases to prevent any collapse in the foundation bed. Grouting can be recommended. But the zone to be grouted, the type of grout to be choose, and the likely extent of the grout penetration under a given pressure. Also the nature of soil and the practical experiences can demonstrate the spacing of grout holes in different soil types.

2- Performing a detailed study for sand dunes around all monumental sites in El Kharga Oasis. This study should include the wind dynamics, rates of dunes movements in each direction, the factors controlling dune movements and their accumulations in such arid environment.

3- Applying all possible techniques to reduce the biological action on all the monumental sites, that is because the biologic effect is very dangerous especially on the relieves of the archeological sites.

III.3. Recommended Plan for Conservation and Restoration of Some Archaeo-logical sites in El Giza Pyramids Plateau and El- Kharga Oasis

III.3.1. Introduction

Conservation process should be applied according to scientific plan depending on scientific documentation and investigation. A plan of work used for restoration and conservation of the Archaeological

sites in Giza Pyramids Plateau and El- Kharga Oasis (Fig.C1) as follows:

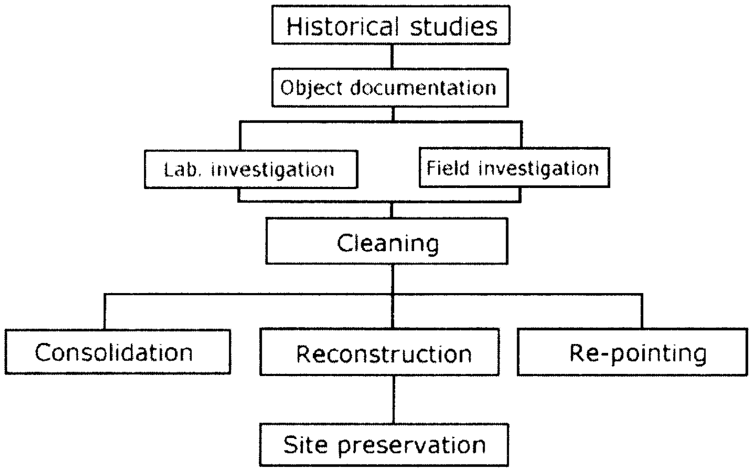


Fig.C1: Plan of the conservation for the Archaeological Sites in El Giza Pyramids Plateau and El- Kharga Oasis

Conservation of any archaeological site should be supported by previous works and scientific studies. Planning, methodology, investigation of the building materials used in the construction of any archaeological building is very important prior to the beginning of treatment, in order to identify the actual state and types of destruction of the constituents of the building materials to choose the best methods for conservation.

III.3.2. Recommended conservation plan for El Giza Pyramids Plateau Site

III.3.2.1. The problem

The Sphinx pyramids and other monuments on the Giza Plateau have been severely damaged by erosion throughout the ages (Emery 1960, Rifai 1951). Attempts to restore it extend all the way back to shortly after it was carved, and it seems that remedial action

was taken at the time it was being carved to fill cracks and add some necessary details to the sculpture (Lehner 1992).

Many studies and experiments have already been undertaken to tackle various aspects of the deteriorating Sphinx. Some of these studies have been published, others remain as unpublished reports. We plan as one of the first steps in this project to compile all previous work on the conservation of the Great Sphinx. We already have a sizeable amount of information, but we hope to compile the previous literature in a volume to be available as a benchmark.

Restoration of the Sphinx was already underway during the Old Kingdom. In addition, restorations in ancient times include works under Tuthmosis IV and Ramesses II (possibly), as well as restorations during the 26th Dynasty. During the Greco-Roman Period, cladding using small stone blocks was used to restore the shape of the body of the Sphinx, which by that time had been severely eroded.

In modern times, clearing sand around the Sphinx and restorations began during the 19th century. They include works by Caviglia in 1818, Berck in 1840, Mariette in 1853, Maspero in 1885, and Baraize from 1925 to 1936 **(in Hawass, 1992).** The restorations by Baraize were the most prominent. They included protecting the back of the neck, lateral support of the head, and constructing a wall from limestone blocks to retain the sand along the northern side of the Sphinx. Selim Hassan dismantled the wall in the 1930s.

In 1955, 1977 and 1979, the Egyptian Antiquities Organization, EAO (currently the SCA) began a restoration project. Subsequently, another project was set in motion to supplant earlier attempts from 1981/2 to 1987 with the main focus on the replacement of the cladding. Earlier efforts failed because of the use of large stones with no attention to the anatomical details of the statue, the use of cement, and lack of supervision by a scientific committee (Hawass 1992: 183-184). From 1989 to 1998, at a cost of approximately 10 million Egyptian pounds **(Hawass, Website: http://www.guardians.net/hawass/)**, a team of sculptors (Adam Hunein and Mahmoud

Mabrouk) and a restorer (Moustafa Abdel-Qader) replaced the cladding with new stones following the shape shown in the photogrammetric maps produced in 1979 by the German Institute. A mortar of lime and sand (1:3) is used after being allowed to congeal for 10-15 days. The chest has been given a protective cover of a course of limestone blocks (Hawass 1992: 186-187).

Initially, some limestone blocks were scavenged from an old wall in the area, but limestones were eventually selected from a quarry in Khamastashar Mayo District (15th May City).

Modern restoration studies include investigations of the stones of the Sphinx and various environmental parameters (Saleh 1981, 1982, Abdel-Sattar 1988, Nasserallah 1985, Hefny 1982). A project sponsored by the American Research Center in Egypt also involved investigations of the deterioration of the stones of the Sphinx (Chowdhury et al. 1990, Gauri 1981, 1992, Gauri et al. 1988 and 1990). The Getti Conservation Institute has also installed a station to monitor wind, precipitation, relative humidity, and condensation. Preliminary results indicate that a strong, sand-bearing northwest wind is the principal source of wind erosion. The results also indicate that both variations in temperature and relative humidity contribute significantly to the surface deterioration of the Sphinx (Preusser, Mackawa and Doehne 1992), confirming the conclusions by Hefny (1982, p. 7). Nakhla (1992) notes that in the period of controlled observation, the left (northern side) of the statue has suffered more than the right side from humidity.

High humidity and condensation from late night hours to early dawn are effective in the chemical reactions that lead ultimately to the formation of a crust of salt that may reach 3 mm in thickness. The crusts lead to flaking. The flakes fall approximately after three months, and a new crust forms rapidly in a few more months. Relative humidity is about 80% in the northern and northwestern areas, and in the chest. There is also a difference of about 5 degrees between the left and right (southern) side of the statue.
Crack monitors also show that there has been a vertical downward movement since January 12, 1990 in most of the northern and

northwestern parts of the Sphinx over a period of nine months. The movement is as much as 2 mm. This may be due to the rapid withdrawal of groundwater, which may cause further structural instability.

Preliminary studies using mathematical models of the aerodynamics around the Sphinx by A. Sherif (Cairo University) and A. Bayoumi (Washington State University) using a wind tunnel indicate that wind erosion is highly effective in the deterioration of the Sphinx. Further detailed investigations are required for reliable results.

There were also preliminary investigations of the structural stability of the Sphinx (Helal 1992). Application of auscultation methods to determine the consistency and homogeneity of the stones of the Sphinx by B. Chagneaud and A. Bouineau in 1990, following an initiative by M. Marc Mamillan (In Esmael, F.1992), revealed a high degree of mechanical inconsistency and non-homogeneity in the Sphinx. It also revealed that the weakest parts of the Sphinx are the basal layers. The head and neck are the strongest and most rigid. The results also showed that the damage is external, without deeper serious damage. The fissures in the upper head, the forehead, and the right ear were noted. Also, adherence of the cement (applied by Baraize) to the head is poor. The study called for an understanding of the geological nature of the ground underneath the monument, its water and salt contents, and the level and seasonal variations of groundwater beneath. It also recommended a comprehensive study of salt content in the Sphinx and the surrounding formations. It also recommended that a system should be devised to prevent groundwater from attacking the statue through capillary action. Investigations of mortars have also been initiated by Nakhla et al. (1992).

From 1988 to 1989, a ministerial commission evaluated previous studies and made recommendations for several specific investigations. A master proposal was prepared at that time. The commission also called for an international symposium, which was held in Cairo from February 29 to March 3, 1992. Dr. Feisal A. Esmael served as the scientific organizer for the symposium and

edited the Proceedings, which provide a valuable document of the state of research up to 1992.

The Sphinx is subject to deterioration primarily due to the following factors:
(1) Wind erosion
(2) Salt weathering
(3) Carbonate solution
(4) Structural instability

Factors that contribute to these processes include wind action, groundwater, humidity, pollution, vibrations, and seismic shocks. Although some preliminary investigations have been carried out, our knowledge of the mechanisms of weathering, the rate of erosion, and the relative role of various weathering agents is still far from clear. Data on wind intensity and direction is still extremely limited. Mathematical models, computer simulations, and wind tunnel experiments are still needed to understand the role of wind in accelerating the deterioration of the Sphinx. The results of these aerodynamic investigations and meteorological data from several locations on the Giza Plateau are necessary to evaluate the feasibility and specifications of wind control devices.

There has been no follow-up to the initial assessment of the concentration of atmospheric pollutants and solid particles by Nasserallah (1985). Similarly, there has been no follow-up to the preliminary study of groundwater by Hefny (1982). In spite of his recommendations to do the following (Hefny 1982):

1) Monitor the level of the water table and the chemistry of the water since stable conditions were not reached during the study.

2) Construct two piezometers west of the Sphinx to evaluate the movement of water through the limestone beds of the Plateau.

3) Undertake a geophysical investigation of the fractures, fissures, and other structures in the underlying rocks.

4) Excavate a pit next to the Sphinx to the level of the water table, and measure the change in humidity with depth to determine the extent of the zone of capillary action. Although a drainage

network has been completed for Nazlet Al-Siman, and there seems to be a considerable drop in the water table, there is still a need, as Hefny (1982, p. 18) recommends, developing a mathematical model of the change in the rates of discharge and its effect on the moisture of the soil below the Sphinx.

Visual observations also reveal that surface water is still close to the surface less than 50 meters south of the Sphinx as indicated by stands of reed vegetation. The ground within the ditch of the Sphinx is also moist in the southeastern corner.

Destruction of the limestone surface of the Sphinx is due both to salt weathering and solution of limestones under the influence of sulfur dioxide (and presumably other sulfur and nitrogen oxides) in atmospheric pollutants. The total concentration of sulfuric acid and other sulfur dioxides exceeds 100 micrograms per cubic meter, with a maximum of 192 micrograms per cubic meter in June 1984. A detailed study of the sources of pollution and its effects on various parts of the Sphinx is necessary. Preliminary investigations by Nakhla (in progress) indicate that complex chemical alterations are taking place, and that, in addition to salt weathering and limestone solution, precipitation of gypsum, and the alteration of clay minerals associated with a release of iron oxides and silica are occurring in certain areas. There is a need to undertake detailed examinations of various parts of the body of the Sphinx and the cladding and to evaluate the role, intensity, rate, and distribution of chemical weathering in order to determine the best methods by which to remedy it. In addition, there is a need to determine the composition of aerosols, which contribute to salt weathering. Pending such studies, any attempts to treat the surface (choice of consolidates or cleaning methods) are premature.

Additional factors that seem to contribute to the deterioration of the Sphinx include surface rain and a variety of organisms; however, the intensity and role of these agents is still not clear. In 1988, the Sphinx was exposed to unusually high levels of rainfall. There is clear evidence of rain drops pitting, as well as rills on the surface of the adobe walls of the Amenhotep Temple. Ants, sparrows, bees, and rats are also active, affecting the Sphinx, the Sphinx Temple, and the temple of Amenhotep.

The collapse of a limestone block from the left shoulder of the Sphinx and the presence of cracks, fissures, and overhanging ledges is alarming. A study of both macroscopic and microscopic fissures and an evaluation of the risk of structural instability are urgently needed.

The use of consolidates, binders, and mortars to strengthen the surface, repel water, and fill cracks and fissures has been a subject of endless debate. During the First International Symposium on the Great Sphinx (1992), several scholars discussed the problem of consolidating agents. Gian Luigi Nicola (1992) suggested that the use of methyl acrylic compound (Paraloid 872) was successful for limestone from Qom Madi, Fayoum. Richard Jaeschke (1992) discussed the use of consolidates. He noted that the use of silanes is controversial, that the use of lime-based treatments could create a dark artificial look and that among synthetic resins; Paraloid 872 has been used for 20 years with no reports of any deterioration. Hanna (1992, p.287) cautioned against the use of organsilanes, and also warned that the use of lime-based treatments caused, in trial areas, a breakdown at the interface between treated and untreated areas (p. 288).

Gauri (1992) suggested the use of ethyl silicate (Wackar's stone hardener OH) instead of Wacker's product H, but he also noted that the application of ethyl silicate has not been tried on a large scale.

The use of coating material to protect the stones from chemical attack and sand blasting will be based on the following criteria, following Amoroso and Vasco (1983):

1. It does form a brittle crust that would spall off.
2. It prevents penetration of outside moisture while allowing inside moisture to escape.
3. It is chemically non-reactive and harmless in use.
4. It does not alter the physical appearance of the stone (transparent and reasonably non-glossy).
5. It is mechanically compatible with the stone.
6. It is economical to use and easy to apply.
7. It is long-lasting and can be repaired or removed.

8. It resists deterioration due to atmospheric conditions, particularly ultraviolet light.

Nakhla (1992) analyzed twenty samples from the mortar used in ancient restorations. The material used was predominantly gypsum. Nakhla (1992), in cooperation with the Building Institute, has selected a mortar from lime and sand. The present study will monitor the durability and effects of this mortar.

Preliminary investigations to evaluate the hazards of earthquakes and other seismic hazards (Albert and Ahmed 1992) reveal the need for a study of the acceleration records, which require a dense instrumental network around the Sphinx site, and of the seismic characteristics of different strata.

Lack of public awareness of the real condition of the Sphinx and of what is required to conserve it is a problem that must be addressed by a conscious policy of public education. There is also a need to follow restoration projects with monitoring to avoid recurrence of restoration problems, and to evaluate restoration and conservation measures. There is also a need, given the shortage of trained restorers and conservators, to use conservation projects for training.

III.3.2.2. Objectives

In view of the various threats to the Sphinx, which were signaled by the collapse of a block from its left shoulder in 1988, and in compliance with the recommendations of the Ministerial Commission, as well as the First International Symposium on the Great Sphinx, the proposed project is formulated in order to conduct the research necessary to conserve the Great Sphinx, as a case study of conserving monuments in Egypt, and to ensure that the replacement of cladding is not compromised by the impact of natural and human-induced environmental factors. Restoration must be conceived within the context of environmental conservation to ensure long-term preservation and protection of monuments.

The present master proposal is the outcome of proposals put

forward previously by Saleh A. Saleh (1981), Fekri A. Hassan et al. (1989), and Hassan Fahmi Imam (1991).

In addition, it takes into consideration the proposals presented during the First International Symposium on the Great Sphinx (1992). These proposals include both strategic plans and operational steps.

Tomaszewski (1992) emphasized the need for environmental conservation. El Baz (1992) provided a general survey of sources of environmental hazards (groundwater, air moisture, wind erosion, air pollution, seismic shaking (Sic.), and tourist traffic). He also provided a general theoretical model of wind circulation, and briefly discussed various measures to protect the Sphinx. Seasmus Hanna (1992) proposed investigations of:

(1) The petrology of the Sphinx (insoluble residue, type of clay, pore space distribution, and soluble salts).

(2) Moisture and temperature variations within the body of the Sphinx through probes.

(3) The sources of structural instability.

(4) Wind erosion. Hanna also recommended the establishment of a computer database to record the area and type of deterioration, salts, watermarks, and structural movements. Esmael, (1992) provided philosophical, managerial, and technical suggestions that must be taken into serious consideration. He knows from bitter experience that in order for a conservation project to succeed, it must be well managed, supported, and funded. A project chief must be given a clear mandate to direct all aspects of work with complete authority. The site may be protected by [vacuum] removal of settling dust, retiling of worn out ground areas, and paving the area immediately adjacent to the statue.

Mark Norman (1992), of the Ashmolean Museum, proposed a program of:

(1) Environmental monitoring (pollutants, moisture, & groundwater).

(2) A study of consolidates.

(3) Removal of cement and gypsum-based restoration at the base of the Sphinx.

(4) Establishing an integrated photographic documentation and computer modeling.

(5) The training of conservators.
(6) An educational program.

Yashimura and colleagues (1992) proposed a program to investigate:
(1) The moisture content of the Sphinx body (cf. Hanna 1992).
(2) The deterioration rate of the Sphinx (flaking, loss of volume, distribution of strength and durability, penetration of weathering, and distribution of faults, fractures and cavities).
(3) Bearing capacity.
(4) Hydraulic gradient.
(5) Mechanical stone properties.
(6) Wind erosion.
(7) Consolidates.

Preusser, et al., 1992, in an unpublished note presented during the symp-osium, noted that it would be advisable in one or two years to open up small portions of the cladding to evaluate possible destruction of the body of the statue behind it. They also noted the need for the following laboratory investigations:

. Maximum capillary rise of water.
. Water sorption isotherms (rock and dust deposits).
. Equilibrium moisture content.
. Sorption rates.
. Hygric expansion coefficient. . Thermal expansion coefficient.
. Depth of thermal and hygric fluctuations.
. Desalinization experiments.
. Measurements of the groundwater moister and salt profile.

Helal (1992) discussed the need for a zone risk map, which included evidence of structural discontinuities and their analysis, geotechnical parameters, probabilities of failure, and zoning of the critical parts of the Sphinx.

In the light of these recommendations the strategic objectives of the current proposal are as follows:

Restoration, maintenance, and conservation in order to maintain the historical and aesthetic integrity of the Sphinx, and to

ensure its structural stability and resistance to environmental hazards and threats.

Public education in order to gain public support, engage the public in conservation efforts, and to minimize negative social or economic developments.

Site management and monitoring to ensure the presentation of the monuments within a cultural context, to accommodate and control tourist traffic, and to monitor human and environmental parameters affecting the durability of the Sphinx.

Training to create a cadre of professional restorers and conservators.

The project is in accord with the strategy of ICCROM, as expressed by the World Heritage Convention, as expressed by Stow (1992), as well as the remarks by Hanna (1992) and Norman (1992) in the Proceedings of the First International Symposium on the Great Sphinx. These specifically include:

(1) Conservation is not restricted to restoration, but aims at identifying and controlling environmental parameters that threaten monuments.

(2) The importance of maintenance and monitoring as key elements in the stages following restoration and environmental intervention.

(3) The need to investigate all sources of instability and deterioration, to create a data base, and to evaluate work already done, diagnose the problems, and to establish a program of a computer modeling and simulation.

(4) The necessity of undertaking public education programs to generate public support for conservation efforts and to mobilize the public to participate in conservation efforts.

(5) The need to establish a site management program to regulate tourist visits and commercial activity in the archaeological sanctuary of the Sphinx.

(6) The necessity of creating a cadre of Egyptian conservators who will work as a team to protect, conserve, and present the Egyptian

monuments, and who will, as a team, deal with the basic scientific research issues characteristic of the Egyptian context (environment, raw materials, and social and economic factors).

(7) The presentation of antiquities within a cultural context to maintain the archaeological integrity of the monument and, at the same time, provide the milieu for educational visits that pose minimum danger to the monuments.

This proposal is a comprehensive, interdisciplinary project with a clear focus on problems, objectives, and methods. The goals of the project include a comprehensive program for the conservation of the Sphinx.

III.3.2.3. Proposed Investigations

The proposed investigations include the following phases:

Phase I

(1) Diagnostic Studies:
- (A) Study of environmental variables.
- (B) Study of the rock properties of the parent rock and the cladding, including the processes and products of deterioration.
- (C) Study of the mechanical (structural) stability of the Sphinx, including features of structural failure.

(2) Educational Program.

(3) Training

Phase II

(1) Computer simulation and modeling.

(2) Restoration and Preservation Studies:
- (A) Study of environmental controls.
- (B) Study of consolidates and preservatives.
- (C) Study of structural restoration and preservation.

(3) Educational Program (cont.).

(4) Training (cont.).

Phase III

(1) Monitoring

(2) Site Management.

(3) Publication and Public Display.

III.3.2.4. Site Management and Presentation

In this category a study of the presentation of the Sphinx within a cultural/education context will be considered. Studies will include landscape and site planning, site tours (number of visitors, pathway, vistas, and on-site information), control of traffic, and the establishment of a small Sphinx museum to provide cultural/educational information and to serve as a source of revenues to the continued conservation of the Sphinx.

III.3.2.4a. Future Monitoring Program

In this category the establishment of a monitoring station to evaluate the various measures adopted to conserve the Sphinx will be undertaken.

III.3.2.4b. Training and Capacity Building

One of the key goals of this project is to establish a team of specialists, conservators, and skilled craft persons. This will be achieved through the employment of junior university graduates and junior Ph. D. recipients, as well as the provision of training through workshops, seminars, and supervised mini-projects.

III.3.2.4c. the Educational Program

Under this category, various activities to enhance the public awareness of conservation efforts will be explored and evaluated, and some will be implemented after testing. The proposed activities include:

(1) Preparation of a booklet for school teachers and children on the Sphinx and conservation

(2) Local, small, moveable exhibit to document restoration and conservation efforts and to acquaint the public with efforts on-site

(3) The use of students from the local community for manual activities (e.g. removing sand)

(4) Public lectures (5) Preparation of an information package for the press.

III.3.3.El-Kharga Oasis Archaeological Sites

III.3.1. The temple of Hibis

After field observation for The temple of Hibis and first investigation of samples it is showing that different destructive factors were attacked the archaeological site of Hibis Temple [and still threaten the existence of this Temple] such as:

- Soil problems and under ground water effects [The main destructive factor of Hibis Temple]
- The effect of micro-biology
- Wind erosion
- Man made deterioration
- Bad restoration

The next plan of conservation is suggested for conserve the Hibis Temple:

- Scientific documentation for the archaeological figures and text.
- Reinforced of all weakness structure units [walls, lintels, roofs etc.]
- Studying and choosing for the best methods of dewatering not only in the Hibis Temple location but also around Hibis area.
- Studying of reconstruction of the missing parts.
- Cleaning the walls surface.
- Re-pointing the missing parts of mortars
- Using suitable methods for fighting the biological and micro-biological effect.
- Consolidation of sandstone and mortar.
- Consolidation of relief and color layers.

III.3.2. The temple of El Nadura

Field observations and first test of building materials for theNaduraTemple is showing that different destructive factors that attacked the archaeological site of NaduraTemple [and still threaten *the existence of this Temple*] such as:-

- The huge daily difference between humidity and temperature
- Wind erosion
- Attacking of sand dunes
- Man made deterioration

The next plan of conservation is suggested for conserve theNaduraTemple as follow:

- Scientific documentation for the archaeological figures and text.
- Investigate the building materials samples.
- Cleaning the stone surface.
- Consolidation of sandstone surface.
- Designing for stop the sand dunes effect.

III.3.3. The Necropolis of El Bagwat

Field observation for the Necropolis of El Bagwat is showing that different destructive factors were attacked the archaeological site of Necropolis of El Bagwat [*and still threaten the existence of those chapels*] such as:

- The huge daily difference between humidity and temperature
- Wind erosion
- Rains
- Biological effects
- Air pollution
- Man made deterioration

The next plan of conservation was suggested for conserve the Necropolis of El Bagwat as follow:

- Scientific documentation for the archaeological chapels.
- Investigate the building materials samples.
- Documentation of the mural paintings that being inside the chapels.
- Cleaning the mural painting.
- Using scientific methods to protect mural painting against micro-biological effect.

- Consolidation of the mural paintings back ground and color layer.
- Isolation of the chapels roofs against rain water.
- Reconstruction of the missing parts especially at the corners.
- Re-pointing of the losing mortar.
- Consolidation of weakness mud- bricks

III.3.4. Qasr El-Ghueita

After field observation for the Qasr El-Ghueita and first investigation of samples it is showing that different destructive factors were attacked the archaeological site of Al Zayyan Temple [*and still threaten the existence of this Temple*] such as:

- Biologic activities (*The main destructive factor of* Qasr El-Ghueita)
- Wind erosion
- Attacking of sand dunes
- Man made deterioration

Conservation study was deals with the currant status of Temple of Qasr El-Ghueita in order to define the suitable way for restoration and protection of Qasr El-Ghueita Temple site as follows:

- Scientific documentation for the archaeological figures and text.
- Using suitable methods for fighting the micro-biological effect [bacteria, fungi. etc.].
- Cleaning the wall surface.
- Re-pointing the missing parts of mortars
- Consolidation of sandstone, mortar and mud brick surface.

III.3.5. Qasr Al-Zayyan

After field observation for the Qasr Al-Zayyan and first investigation of samples it is showing that different destructive factors were attacked the archaeological site of Al Zayyan Temple [*and still threaten the existence of this Temple*] such as:

- The effect of birds and bees [*The main destructive factor of Al Zayyan*]
- Wind erosion and sand dune hazard
- Man made deterioration

- Geological defect of sandstone

The next plan of conservation is suggested for conserve the Qasr Al-Zayyan Temple as follow:

- Scientific documentation for the archaeological figures and text.
- Investigate the building materials samples.
- Using suitable methods for fighting the biological effect [birds and bees].
- Consolidation of sandstone and mud brick surface.

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APPENDIX

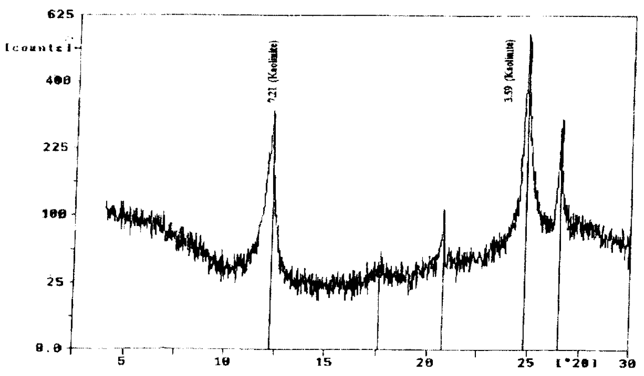

Fig.X1a: X-Ray pattern showing kaolinite predomination, sample at 2 m depth from surface, Hibis Temple, El Kharga Oasis

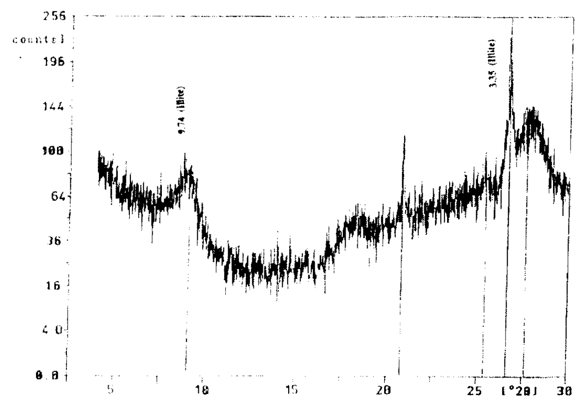

Fig.X1b: X-Ray pattern showing illite predomination, sample at 2 m depth from surface, Hibis Temple, El Kharga Oasis

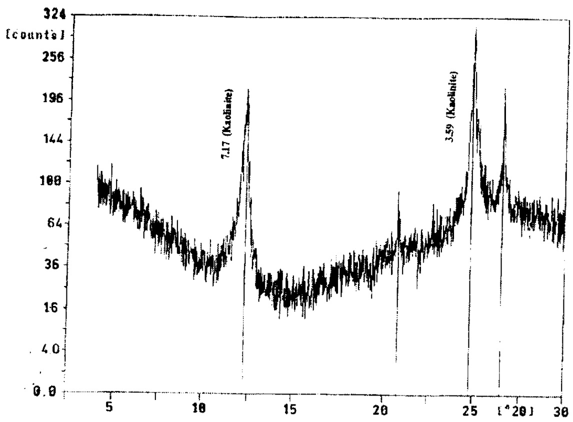

Fig.X2a: X-Ray pattern showing kaolinite predomination, sample at 12 m depth from surface, Hibis Temple, El Kharga Oasis

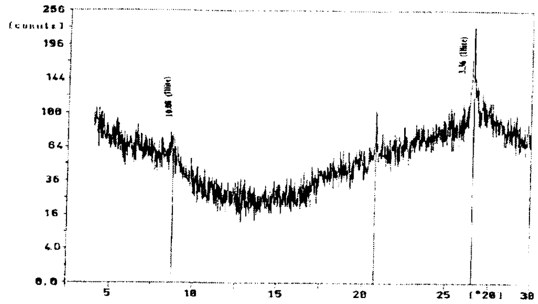

Fig.X2b: X-Ray pattern showing illite predomination, sample at 12m depth from surface, Hibis Temple, El Kharga Oasis

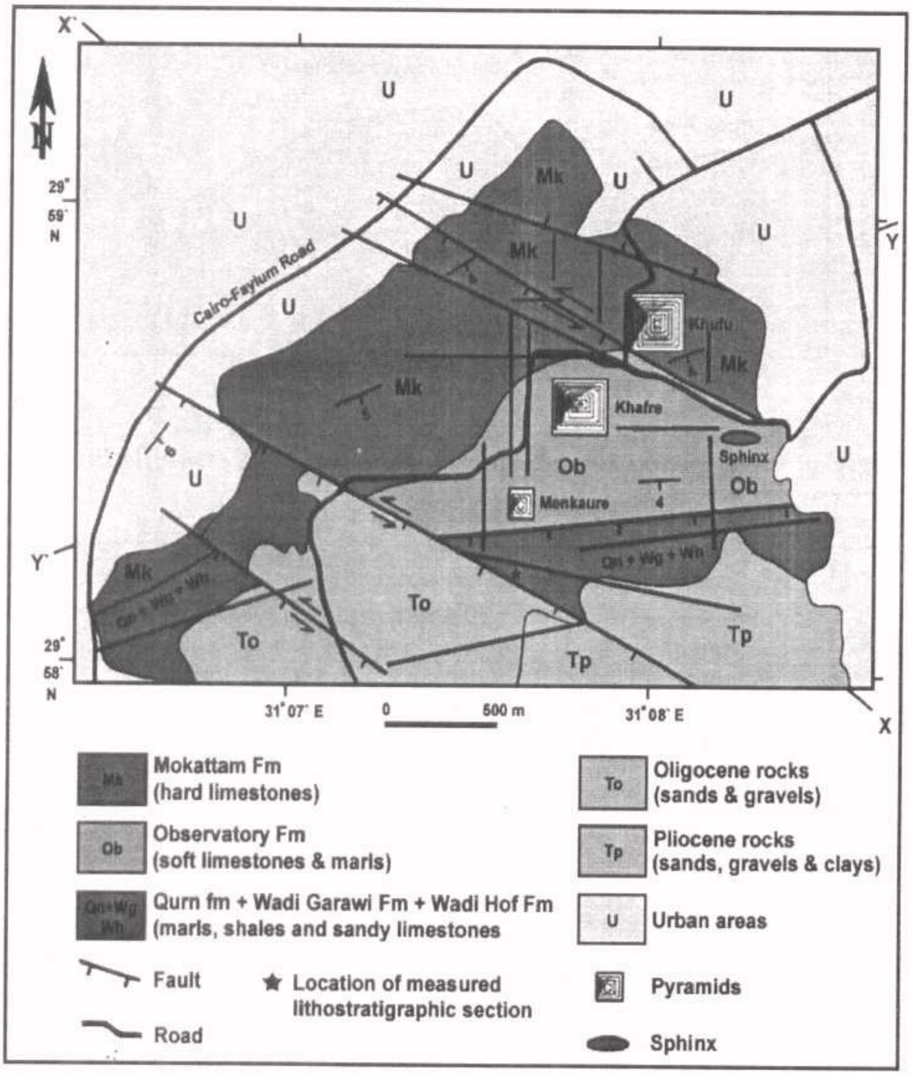

Fig.P5: Geological map for the Giza Pyramids plateau based on colour composite satellite image interpretation and field studies.

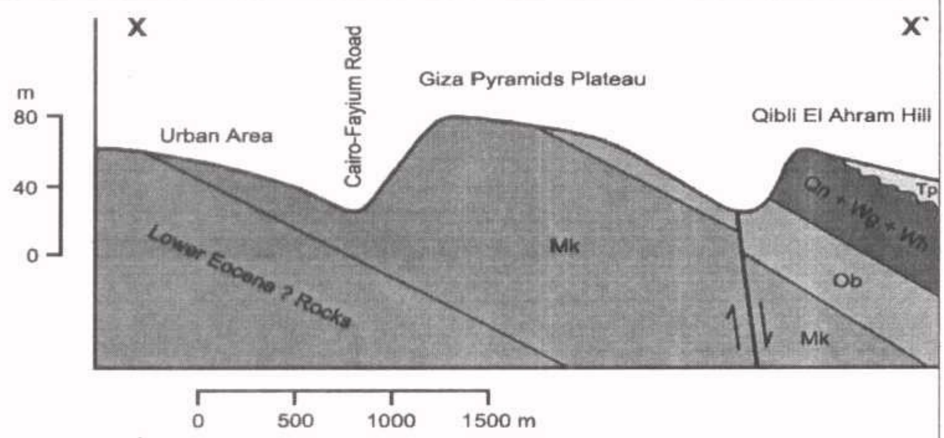

Fig.P 6: Geological cross section X- X` El Giza Pyramids Plateau

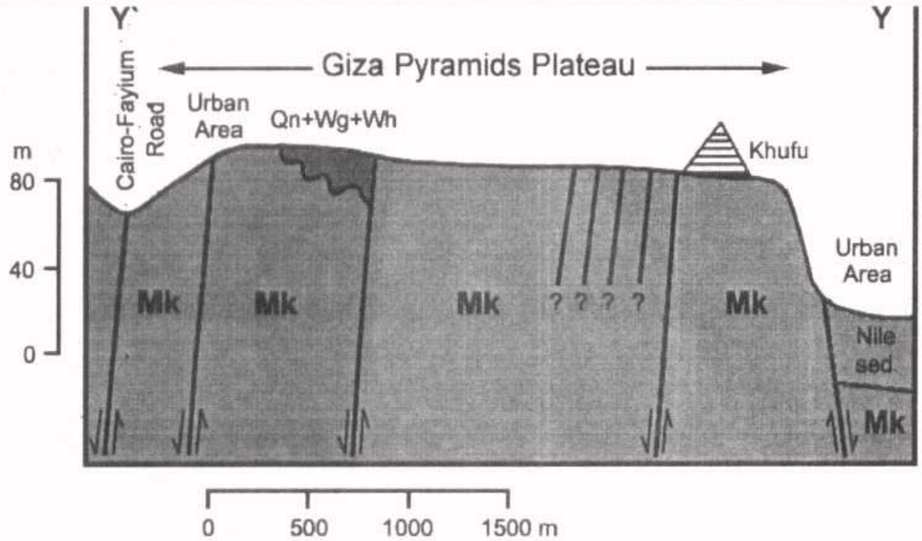

Fig.P 7: Geological cross section following SW-NE direction, at El Giza Pyramids Plateau

Note: For explanation please see Fig.P5

Fig.S1: General view of Sphinx

Fig.S2: Limestone and marls form the main bedrock of Sphinx site

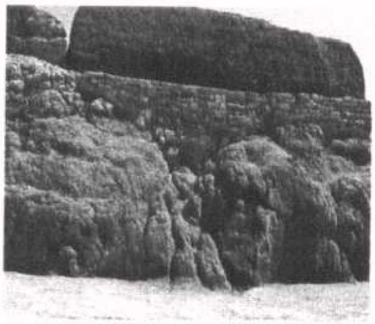

Fig.S3: Clay beds are exposed to the east of Sphinx site

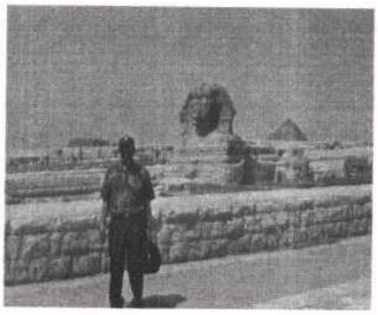

Fig.S4: Sphinx showing the main host rocks affected by differential weathering on marl and limestone beds

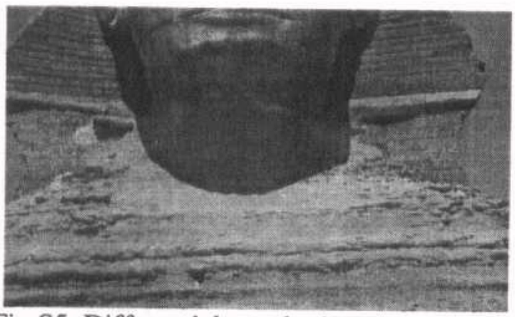

Fig.S5: Differential weathering on marl and limestone beds, upper part of Sphinx body

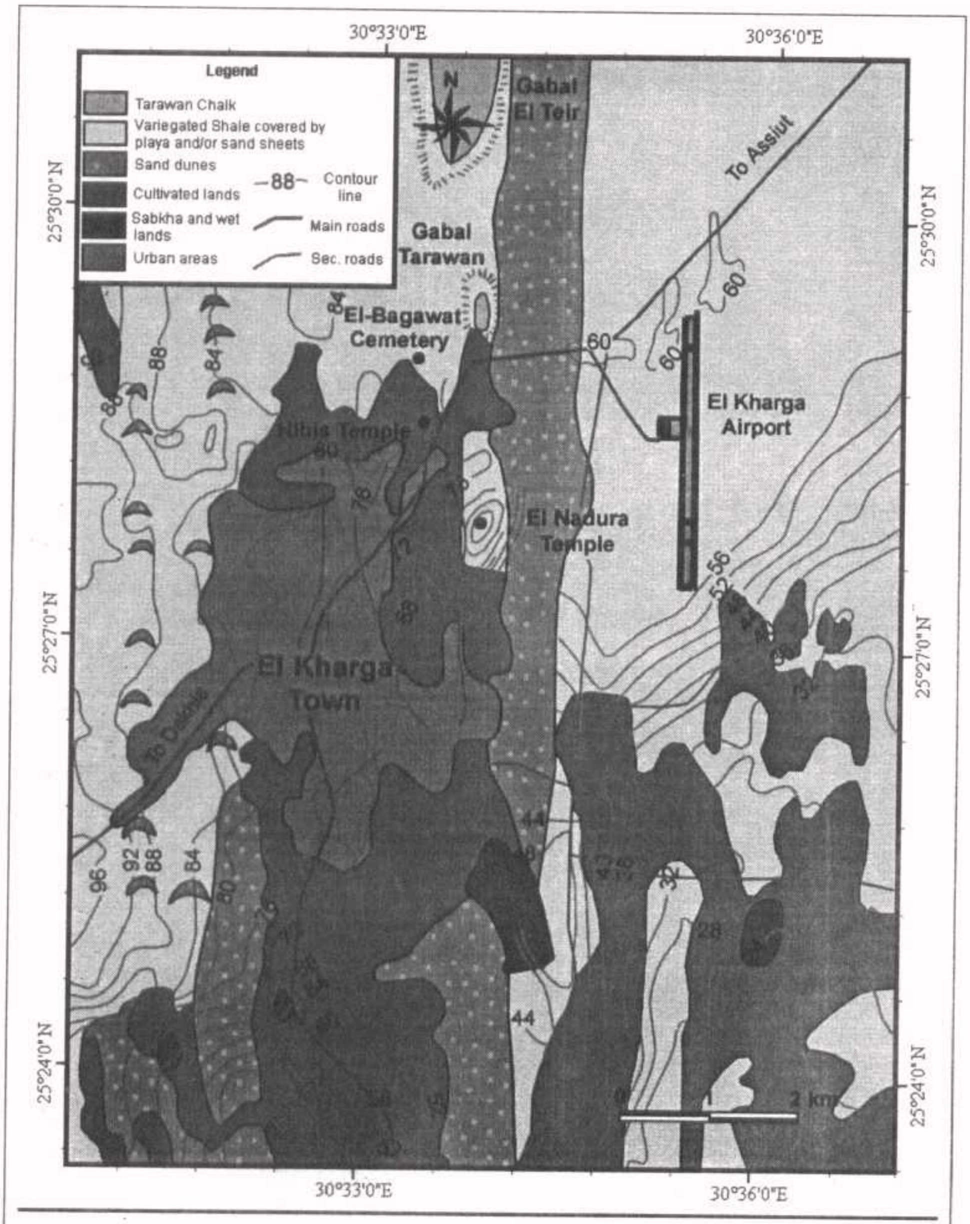

Fig.K5:Geologic map for the northern part of El Kharga Oasis including some monumental sites

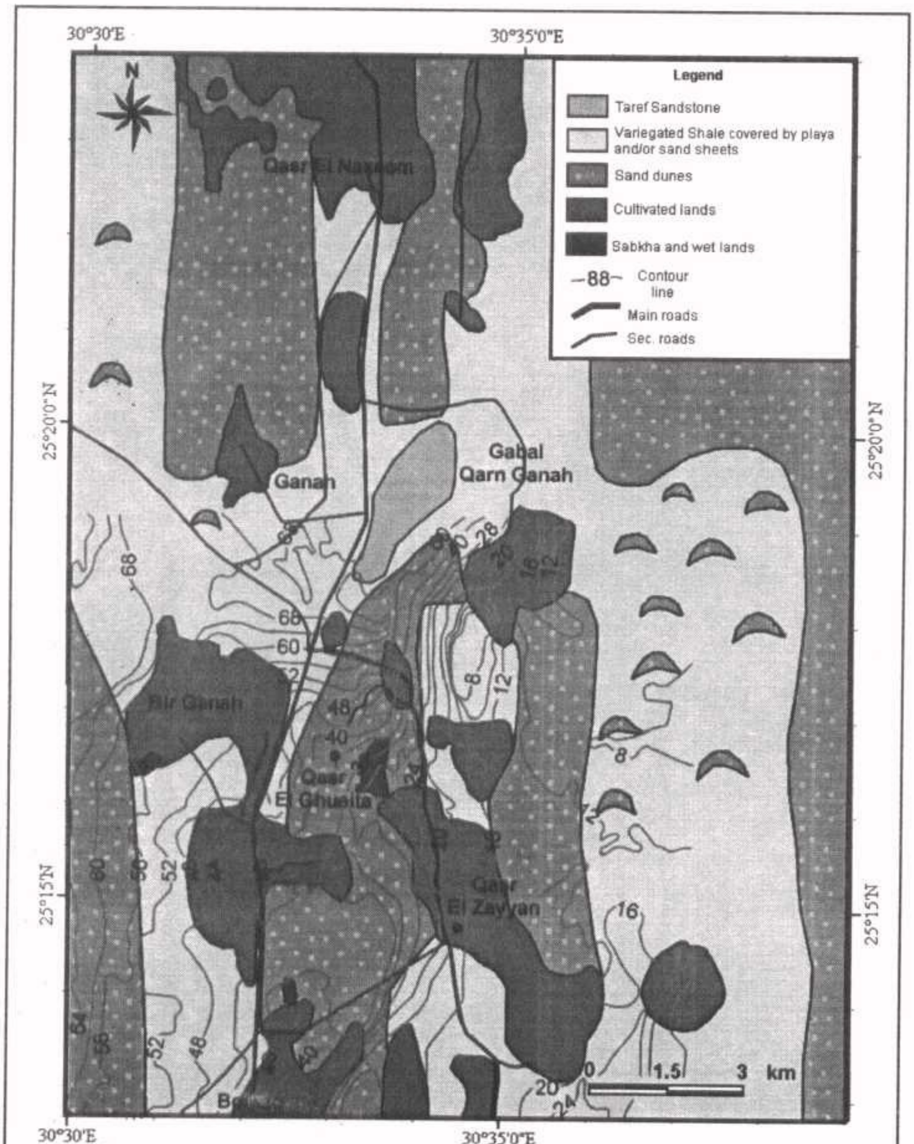

Fig.K10: Geologic map for the central part of El Kharga Oasis including some monumental sites

Wind erosion and sand accumulation

Fig.Z3: Main entrance, El-Zayyan Temple showing some sand accumulation

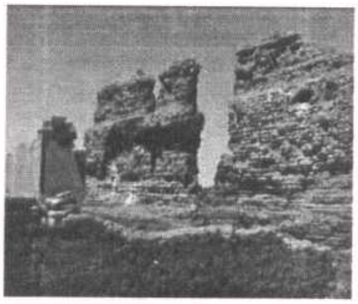

Fig.Z4: Wind erosions affecting the mud bricks wall [mortar and brick units]

Fig.Z5: Mud brick ruins is a soft materials especially against weathering process

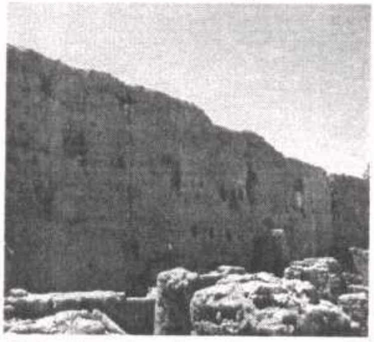

Fig. Z6: deterioration due to combined effect of erosion and bio-effect

Biological hazard

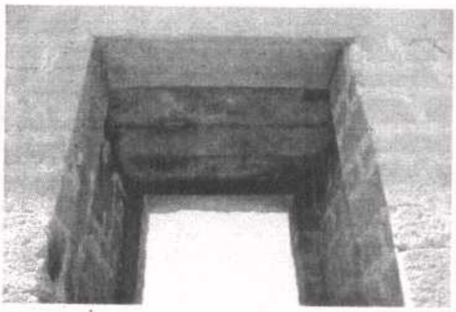

Fig.Z7: Bio-deterioration fungi effect in the sealing blocks of the main entrance

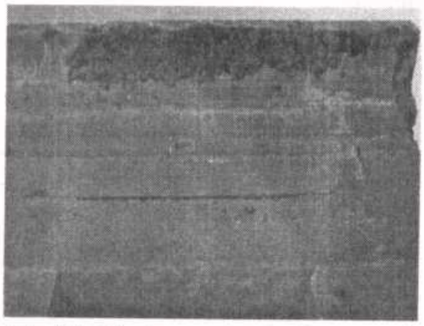

Fig.Z8: Nests groups in the rear of entrance gate.

Fig.Z9: The holy of holies has bio-deteriorated effects with Hornet nests and Bird's excretion.

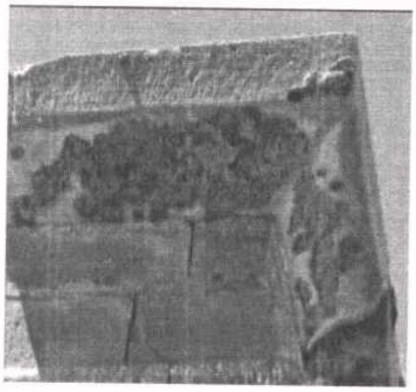

Fig.Z10: Hornets always choosing the shadow places to build its nests

Fig.Z11: Hornet nests between sandstone and Suof mortar

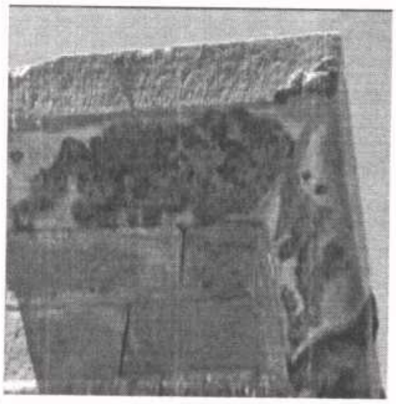

Fig.Z12: Hornets always choosing the shadow places to build its nests

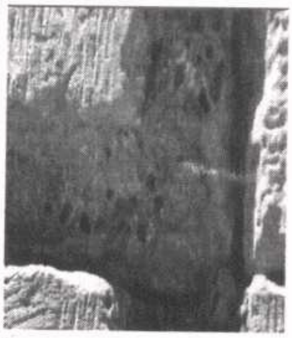

Fig.Z13: Hornet nests composed of clay minerals + organic materials + adhesives

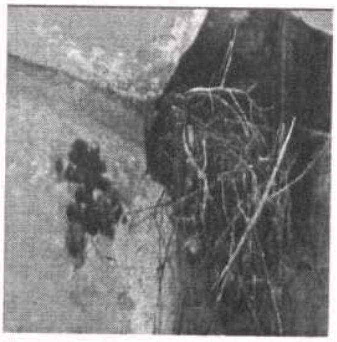

Fig.Z14: Bird nest in the main entrance gate

Fig. SD1: Sand sheets partly cover El Qarn north of El Ghaueita Temple

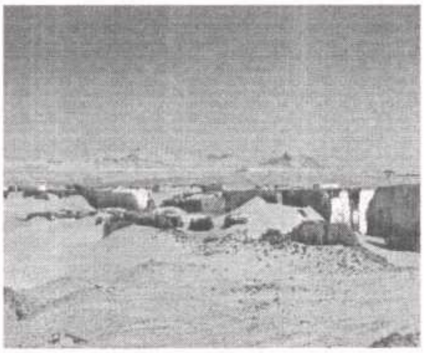

Fig. SD2: Sand dunes destroy completely a village, G. El Qarn, north of El Ghaueita Temple

Fig. SD3: Sand dunes completely destroy a village, north of El Ghaueita Temple (Third day)

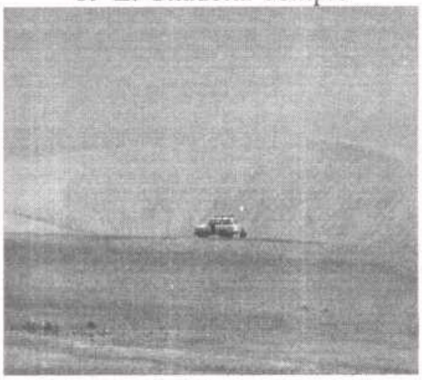

Fig. SD4: A part of the eastern sand dune belt to the east of G. El Qarn, north of El Ghaueita Temple

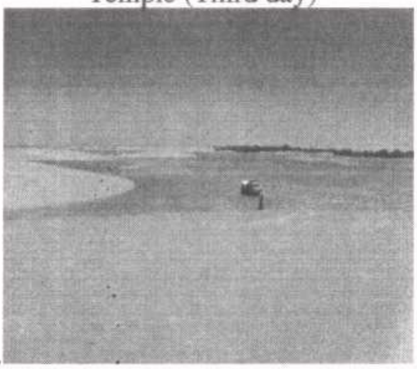

Fig. SD5: A part of the huge western sand dune belt, Ganah village, north west of El Ghaueita Temple

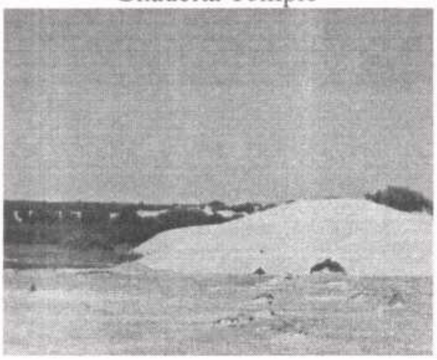

Fig. SD6: A part of the western sand dune belt is moving toward the cultivated land in Ganah village

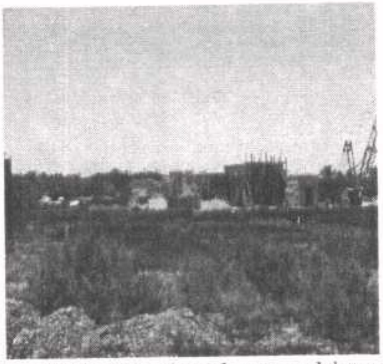

Fig. H20: Showing dense cultivated zone surrounding Hibis Temple

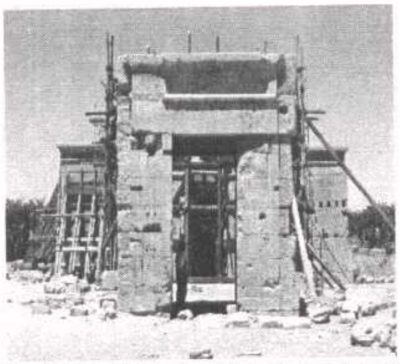

Fig. H21: Showing dense cultivated zone behind Hibis Temple

Fig. H22: Seepage water bond in the vicinity of Hibis Temple

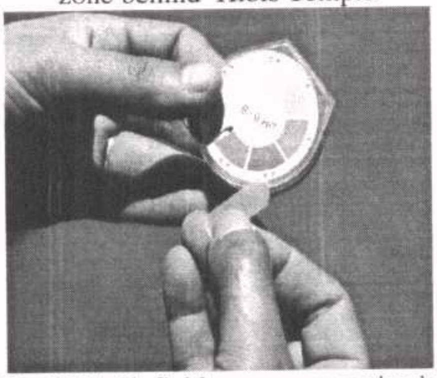

Fig. H23: Ph field measurement in site Seepage water bond in the vicinity of Hibis Temple

Fig. H24: Seepage water bond in the Vicinity of Hibis Temple ,but few meters far from photo in fig. H55

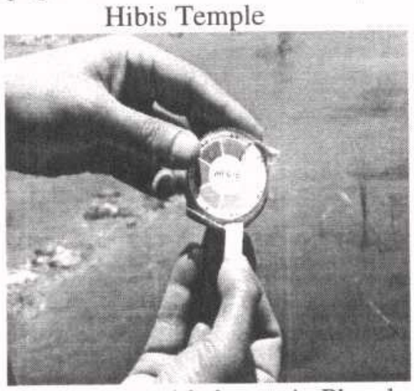

Fig. H25: Rapid change in Ph value for seepage water bond in the vicinity of Hibis Temple

المكتب المصري للاستشارات الجيولوجية (إجكو)

EGYPTIAN GEOLOGICAL CONSULTING OFFICE (EGCO)

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PRESIDENT

Prof. Abdel Aty B. Salman

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**Associate Prof. in applied geology, 1980, Prof. of applied geology, 1985, Vice Chairman, NMA, 1998-1999, Chairman, NMA, 1999-2000. 40 published scientific works, supervised 15Ph.D.and 21 M.Sc. thesis covering various geological fields*

ABOUT US

The Egyptian Geological Consulting Office (EGCO) was established in 1981. Registerd in the Egyptian General Petroleum Corporation ***(EGPC)*** *as Consultant since more than 20 years. We provide the following services:*

1. ***Geologic studies and consultations for oil exploration.***
2. ***Environmental studies for resorts during construction and operation for mitigation of the negative effects on the surrounding environments.***
3. ***Engineering geological studies for site selection of the engineering projects.***
4. ***Application of geological studies on mitigation of the natural hazards on monumental sites***
5. ***Evaluation of ore minerals, industrial minerals and building raw materials occurrences***
6. ***Reviewing scientific reports related to geology and environment.***

CONSULTANTS COOPERATIVE FIRMS

EGCO *cooperates with highly experienced and qualified earth resources and engineering specialists. In addition to their extensive practical experience, they are of high academic levels.*

EGCO *has formal and informal relations with other consulting firms and cooperative scientific organizations, in Egypt and overseas. These relations make* ***EGCO*** *able to provide integrated services to his clients. The following are examples of these firms:*

* *Airborne Survey and Remote Sensing Center of Nuclear Industry* ***(ARKEN)****: Shijiazhuang Hebei, China.*

* *Geochemistry Consulting Office (Geochemical), El Mohandseen, Cairo, Egypt.*

* *Soil investigation and Foundations unit, Faculty of Engineering, Ain Shams University, and Cairo, Egypt*

* *Digital Images for GIS applications, El Maadi, Cairo, Egypt*

* *Geological Departments in the Faculties of Science of: Cairo University, Ain Shams university, El Azhar University and Helwan University, Cairo, Egypt*

SAMPLES OF THE PERFORMED PROJECTS

I. Geological Studies for Oil Exploration

* ***Project:*** *Photo geological Study of Gebel El Maghara - Risan Aneiza Environs, North Sinai, Egypt. (6 months, 81/1982)*
Client: *International Egyptian Oil Company (I.E.O.C.), Cairo, Egypt*

* ***Project:*** *Utilization of Landsat Imagery in Structural Analysis of Esh El Millaha - Gebel Zeit Ranges, Eastern Desert, Egypt, (month, 1984)*
Client: *Marathon Petroleum Egypt, Ltd., Maadi, Cairo, Egypt*

* ***Project:*** *Photo geologic Study of Wadi Feiran and Ras Garra Environs, Sinai, Egypt. (5 moths, 85/1986)*
Client: *Belayim Petroleum Co. (Petrobel), Cairo, Egypt*

* **Project:** *Bibliography of Geology and Related Sciences Concerning Western Desert, Egypt. (1732-1984)*
Client: *Egyptian Geological Consulting Office "EGCO", Cairo, Egypt. A.B. Salman*

II. Environmental Studies

* **Project:** *Environmental study for the site of El Gharandal Tourist Village, Ras Sudr, Sinai, Egypt. 1995*
Client: *Sinai Tigers for Tourist Development. Cairo, Egypt*

* **Project:** *Environmental study for the site of Style Rsourt, Hughada, Red Sea, Egypt, 1995*
Client: *Egyptian-Arabian Engineers Comp., Cairo, Egypt*

* **Project:** *Environmental study for the site of Keryazy Tourist Village, Safaga, Red Sea, Egypt, 1995*
Client: *Keryazy Comp., Cairo, Egypt.*

* **Project:** *Environmental study for the site of Marleen Beach Village, El Sokhna, Gulf of Suez, Egypt, 1995*
Client: *El Ain Company for Tourist Investment, Cairo, Egypt*

* **Project:** *Environmental study for the site of the Tourist Villages in the locations no: 2, 7, 8, and Taba Golden Coast, Gulf of Aqaba, Sinai, Egypt, 1996-1998*
Clients: *Several investments tourist Companies, Egypt.*

III. Site Geologic Studies for Engineering Projects

* **Project:** *Earthquake Risk Survey, Gebel Zeit, Red Sea, Egypt. (1 Month, 1983).*
Client: *Esso Egypt Inc., Cairo, Egypt*

* **Project:** *Earthquake Hazard and Ground Acceleration at the Sites of Cairo 500 KV and Bassous 500 KV Substations, Cairo Environs, Egypt (2 months, 1992)*
Client: *Abb Asea Brown Boveri, Cairo, Egypt*

* **Project:** *Study of Sabkha and Geology of the Escarpment Slopes, Qattara Depression, Western Desert, Egypt. (7 months, 86/1987)*
Client: *Hydro-Power Plants Executive Authority, Ministry of Electricity and Energy, Egypt*

* ***Project:*** *Geological - Engineering study for underground water pipeline crossing El Asher Men Ramadan - Belbes Road. (2 months, 1998)*
Client: *El Kadessia Contracting Company, Belbes, El Sharkia, Egypt*

IV. Site Geologic Studies for Archeological sites

Project: *Minimizing of the natural hazards on some monumental sites in Giza Pyramids Plateau and El Kharga Oasis, Western Desert, Arab Republic of Egypt by studying the geological phenomenon (9 months, 2005)*
Client: UNESCO, Cairo, Egypt

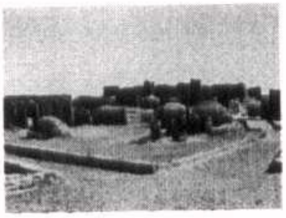
V. Undergroud Water Exploration

* ***Project:*** *Preliminary Visibility Study for Ground Water Potentiality in Gebel Iweibed Region, North Eastern Desert, Egypt. (1 month, 1983)*
Client: *General Nile Company for Desert Roads, Cairo, Egypt*

VI. Mineral Exploration

* ***Project:*** *Searching for Barite ore, East Gebel Radwan Concession, Bahariya Oases, and Western Desert, Egypt. (2 months, 1986)*
Client: *Egyptian Geological Consulting Office "EGCO", Cairo, Egypt*

تقليل المخاطر الطبيعية
على بعض مواقع الآثار
بهضبة أهرامات الجيزة
والواحات الخارجة بالصحراء الغربية بمصر
وذلك بدراسة الظواهر الجيولوجية

المكتب المصرى للإستشارات الجيولوجية (EGCO)
د. عبد العاطى بدر سالمان

تمت الدراسة تحت مظلة اللجنة الوطنية المصرية للتربية والعلوم والثقافة (اليونسكو)
(مشروع رقم ١٨٣٢٢٤٠٩ فى إطار برنامج المساهمة لعامى ٢٠٠٢/٢٠٠٣)

٢٢ ديسمبر - ٢٠٠٥

مقـــدمة

مصر ذات الحضارة العريقة التي تمتد إلى سبعة آلاف عام مضت يشـــهد على ذلك الآثار التي تزخر بها في كل أرجائها والتي شهدت حضـــارات متعاقبـــة فرعونية ورومانية وإغريقية وقبطية وإسلامية. هذه الآثار التي لا تقدر بثمن سواء من الناحية التراثية أو من الناحية الاقتصادية إذ إنها عماد السياحة التي تشكل أحد أعمدة الاقتصاد والتنمية في مصر والتي يجب الحفاظ عليها من التـدهور نتيجـة العوامل الجيولوجية أو العوامل البيئية الطبيعية أو التي بفعل الإنسان.

ومن منطلق تبني اللجنة الوطنية المصـرية للتربيـة والعلـوم والثقافـة «يونسكو» الحفاظ على التراث الثقافي والطبيعي، وكذلك إتاحة الفرصة لاشـتراك الهيئات البحثية غير الحكومية في أنشطتها فقد تقدمت إلى منظمة اليونسكو باقتراح دعم المشروع المقدم من المكتب المصري للاستشارات الجيولوجية تحـت اسـم «تقليل المخاطر الطبيعية على بعض مواقع الآثـار بهضـبة أهرامـات الجيـزة والواحات الخارجة بالصحراء الغربية بمصر وذلك بدراسة الظواهر الجيولوجية»، وقد وافقت منظمة اليونسكو على هذا الطلب.

ويشمل هذا المشروع دراسة الظواهر الجيولوجية التي تؤثر فـي بعـض المواقع الأثرية مثل أهرامات الجيزة إحدى عجائب الدنيا السبع وتمثال أبو الهول، وعدة مواقع أثرية أخرى في الواحات الخارجة جنوب الصحراء الغربية المصرية مثل معبد هيبس ومعبد الناضورة والبجوات ومعبد الغويطة ومعبد قصـر زيـان، إذ إن وجود هذه الآثار الآن في مناطق صحراوية وجبلية يجعلها عرضة لتـأثير العوامل الجيولوجية التي قد تؤدي إلى تدهورها أو تدميرها وفي ذلك خسارة كبيرة لا يمكن تعويضها.

وفي هذه الدراسة تم معالجة الصور الفضائية لتلك المواقع وذلـك لعمـل خرائط جيولوجية توضح معظم الظواهر الجيولوجية الهامة فيها، كما تـم فحـص المواقع الأثرية ميدانيًا والتوصية بكيفية التقليل من هذه المخاطر على هذه المواقع الأثرية الهامة.

واللجنة الوطنية المصرية تأمل أن يكون لهـذه الدراسـة فائـدتها لـدى المتخصصين والمعنيين وصانعي القرار.

تقليل المخاطر الطبيعية علي بعض مواقع الآثار بهضبة أهرامات الجيزة والواحات الخارجة بالصحراء الغربية بمصر وذلك بدراسة الظواهر الجيولوجية

مقـــــدمة

لما كانت الآثار المصرية تمثل ثروة قومية وتراثا ثقافيا عظيما، ولما كان الحفاظ عليها يمثل هدفا ساميا يخدم الاقتصاد القومي والتراث الثقافي والحضاري المصري، فقد تقدم المكتب المصري للاستشارات الجيولوجية إلي اللجنة الوطنيـــة المصرية للتربية والعلوم والثقافة (اليونسكو) باقتراح لإجـــراء دراســـة للظـــواهر الجيولوجية لبعض مواقع الآثار بهضبة أهرامات الجيزة والواحات الخارجة وذلك لتقليل المخاطر الطبيعية علي تلك المواقع الأثرية، وقد تمت الموافقة مـــن قبـــل اليونسكو علي إجراء الدراسة وأدرجت تحت مشروع: *(EGY 18322409)* .
وكذلك تم الحصول علي موافقة من المجلس الأعلى للآثار المصرية علي تنفيذ هـــذه الدراسة بتاريخ ١٨ سبتمبر ٢٠٠٥م.

وافقت اللجنة الوطنية المصرية للتربية والعلوم والثقافة (اليونسكو) علي خطة ومراحل الدراسة التي اقترحها المكتب المصـــري للاستشارات الجيولوجية والتي اشتملت علي أربعة مراحل هي : مرحلة الإعداد والتجهيز– مرحلة الدراسة الميدانية للظواهر الجيولوجية – مرحلة الدراسة المعملية– ومرحلة إعداد التقرير النهائي.

الخـــلاصـــة

يشتمل هذا المشروع علي دراسة الظواهر الجيولوجيـــة في بعض مواقع الآثار بمنطقتي هضبة أهرامات الجيزة والواحات الخارجة بالصحراء الغربية، وذلك بغرض تقليل المخاطر الطبيعية علي تلك المواقع الأثرية الهامة. ومن خلال هذه الدراســـة تم معالجة الصور الفضائية التفصـــيلية لتلك المواقع وذلك لعمل خـــرائط جيولوجية مبدئية، وخلال الدراسات الميدانية تم التحقق من الوحدات والتراكيب الجيـــولوجية المستنبطة لتحويل تلك الخرائط الأوليـــة إلي خرائط جيولوجية والتي تحتوي علي معظـــم الظواهر الجيولوجية الهامة. وقد تم فحص المواقع الأثرية

وتجميع الملاحظات الميدانية وخاصة العوامـــل التي تسبب تدهورًا لتلك الآثار وتصويرها كلما سمحت الظروف.

وقد اتضح خلال هذه الدراسة أن المخاطر الطبيعية في هضبة أهرامات الجيزة يتحكم فيها عدد من العوامل أهمها نوعية الصخور السائدة وطبيعة صخور طبقات الأساس ومناطق الصدوع والشقوق. وتجدر الإشارة إلي أن بعضًا من هذه الصدوع يحتمل أن تكون من النوع النشط (Capable faults)، زيادة علي ذلك وجود نطاقات شديدة التغير مثل ظاهرة (Karstification phenomenon) والكهوف في طبقات الحجر الجيري نتيجة لتأثير التراكيب الجيولوجية والتغيرات الجيوكيميائية وحركة المياه الجوفية والأمطار والرطوبة وعوامل التلوث من البيئة المحيطة تشكل مخاطر أخري لا يستهان بها. كذلك اتضح وجود مخاطر أخري نتيجة لعمليات التعرية والتجوية علي تجمع الآثار في منطقة أهرامات الجيزة.

ونتيجة للمخاطر التي تم تحديدها من خلال هذه الدراسة في منطقة هضبة الأهرامات يمكن التوصية بما يلي:

- القيام بتثبيت ومعالجة وتدعيم المواقع الضعيفة والتي لوحظ وجود العديد من الكتل الصخرية الآيلة للسقوط علي حافة الهضبة الصغيرة القريبة من هرمي خفرع ومنقرع. كما يجب معالجة نطاق الصدع المتجه شمال غرب – جنوب شرق والذي توجد به العديد من الشقوق التي تقطع طبقة الأساس وتضعفها في الجزء الشمالي الشرقي لهرم خوفو.
- تطبيق بعض الدراسات الجيوفيزيقية لتحديد مسارات الصدوع وخاصة التي تضرب في اتجاه شمال غرب– جنوب شرق وكذلك مواقع وجود الكهوف في هضبة الأهرامات. وترجع أهمية تلك الدراسات في أنها تساعد على إيجاد أحسن الحلول لعمليات الترميم وتقوية مناطق الضعف وتلاشي المخاطر المحتملة في المستقبل.
- دراسة التراكيب الجيولوجية الحديثة (Recent tectonics). وتساعد هذه الدراسة على تحديد الصدوع المحتمل ارتباطها بالزلازل المؤثرة والتي تمثل خطرًا حقيقيًا على مجمع الآثار بهضبة الأهرامات. ويجب أن تشمل تلك الدراسة المقترحة مسح للصدوع السطحية لتحديد الأنواع النشطة منها، وإذا تم التحقق من وجود صدوع نشطة فإنه يتحتم تحديد أعمارها.

- أما بالنسبة لأبي الهول، فقد أوضحت الدراسة أنه قد تم نحته في طبقات من الحجر الجيري المارلي والمارل، وتتصف هذه الصخور بعدم الصلابة (Soft rocks) ، وأنها قد تأثرت بالعديد من الشقوق والفواصل المتقاطعة. زيادة علي ذلك فإن أبي الهول نفسه قد تأثر بالعديد من الشقوق، وتجدر الإشارة بأن تلك الشقوق والفواصل تمثل خطرًا حقيقيا علي أبي الهول بالإضافة إلي عوامل التدهور الأخري. ومن ناحية أخري فإنه في حالة حدوث زلزال ولو بقوة متوسطة بالقرب من منطقة الأهرامات فإن أبي الهول سوف يكون أكثر الآثار تضررا. ومن هنا تظهر أهمية التوصية بتحديد مواقع الصدوع النشطة (Capable faults) في الجزء الشرقي لهضبة الأهرامات.
- ومن الملاحظات الهامة نتيجة لدراسة الظواهر الجيولوجية حول منطقة أبو الهول مخاطر المياه الجوفية حيث لوحظ تشبع بعض الأجزاء السفلي منه بالرطوبة، وذلك يرجع إلي موقع أبو الهول علي مستوي منخفض بالنسبة لهضبة الأهرامات، بالإضافة إلي قربه من قرية نزلة السمان العامرة بالسكان. لذلك نوصي بملاحظة مستوي منسوب المياه الجوفية والحفاظ عليه عند مستوي آمن لدرء مخاطر المياه الجوفية وتأثيراتها السلبية علي أبي الهول.

أما عن منطقة الواحات الخارجة، فقد تم دراسة الظواهر الجيولوجية في عدة مواقع أثرية اشتملت علي معبد هيبس ، ومعبد النادورة البجوات، ومعبد الغويطة ومعبد قصر زيان. وقد أوضحت هذه الدراسة أنه من أهم الظواهر المؤثرة، والتي يمكن أن تمثل بعض الأخطار علي تلك المواقع الأثرية، هي المياه الجوفية (خاصة في موقع معبد هيبس) وطبيعة التربة ونوعية المواد المستخدمة في البناء والكثبان الرملية والشقوق والفواصل، بالإضافة إلي العوامل البيولوجية. وبناءا علي دراسة الظواهر الجيولوجية وتفحص البيئة المحيطة بتلك المواقع الأثرية بمنطقة الواحات الخارجة، يمكن التوصية بما يلي لتقليل المخاطر علي تلك الثروة القومية من الآثار:

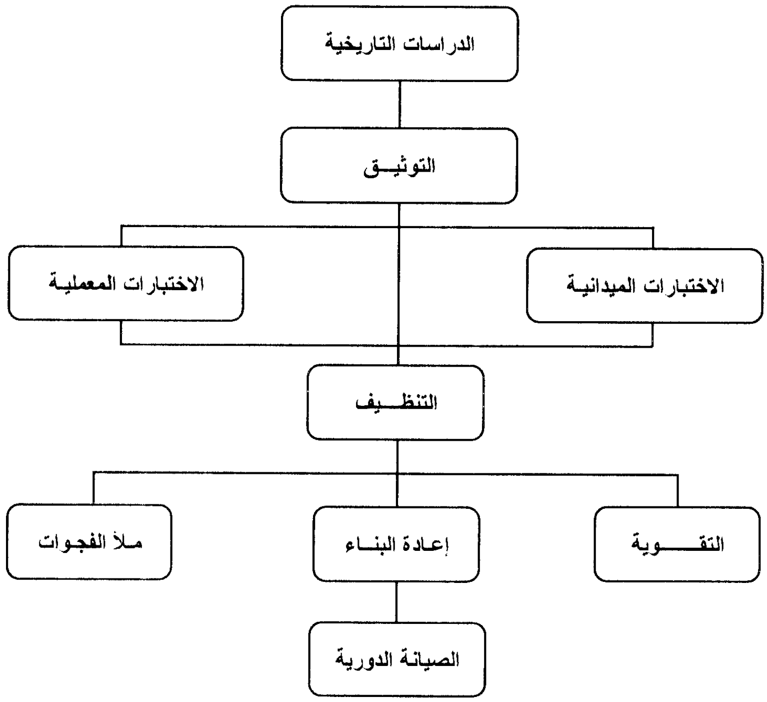
- لابد من دراسة وضع المياه الجوفية بالتفصيل في منطقة معبد هيبس، والعمل علي الحفاظ علي مستواها عند الحد الآمن بحيث لا تتضرر منها مباني المعبد والتي يتم ترميمها حالياً (٢٠٠٥) ويتم ذلك بحجب حركة المياه الجوفية ومياه الرشح من الأراضي المنزرعة حوله، وذلك بعمل بعض الحواجز العازلة

علي أسس تقنية سليمة. كذلك يتم تخفيض مستوي المياه الجوفية في التربة الموجودة تحت المعبد، ولكن لا بد أن يتم عمل ذلك علي أساس علمي وهندسي بحيث لايتسبب في أي انهيار في تربة الأساس نتيجة لعدم التوازن في الضغوط في بيئة المعبد. ويقترح تقوية طبقة الأساس بالمعبد وخاصة أنها تربة طينية ذات سمك كبير.

- إجراء دراسة تفصيلية عن الكثبان الرملية بالواحات الخارجة مع التركيز علي الكثبان الموجودة بالقرب من المواقع الأثرية ويجب أن تشمل تلك الدراسة: ديناميكية الرياح ومعدل تقدم الكثبان الرملية في جميع الاتجاهات والعوامل التي تتحكم في تجمع تلك الكثبان وأثر تلك الكثبان علي المنشآت الأثرية ومشروعات التنمية.
- تطبيق جميع التقنيات الممكنة لتقليل مخاطر العوامل البيولوجية علي تلك الآثار. ويرجع ذلك إلي أن التأثيرات البيولوجية تعتبر من أهم المخاطر التي تتعرض لها الآثار في تلك المنطقة وخاصة النقوش والكتابة، وقد لوحظ أن بعضا منها قد دمر بالكامل بسبب التأثيرات البيولوجية.
- وفي نهاية التقرير العلمي لهذه الدراسة، تم وضع خطة للحفاظ علي تلك الآثار وصيانتها وترميمها في موقعي هضبة الأهرامات والواحات الخارجة. وتشتمل هذه الخطة علي المراحل اللازمة لصيانة المواقع الأثرية بدءًا من الدراسة التاريخية للأثر وجمع البيانات المطلوبة والدراسات المعملية والحقلية حتى عمليات الصيانة والترميم للوصول بالأثر إلي حالة قريبة من حالته الأصلية بقدر الإمكان. وكذلك تم التركيز في هذه الخطة علي أبي الهول وذلك لإنقاذه من التدهور والحفاظ عليه. وقد اشتملت هذه الخطة المقترحة أيضًا علي صيانة وترميم مواقع الآثار بالواحات الخارجة والحفاظ عليها من التدهور، ومن أهم هذه المواقع معبد هيبس، الناضورة، البجوات، الغويطة وقصر زيان. وتعتبر هذه الخطة ذات نفع كبير ويمكن تطبيقها بسهولة، كما تفيد في الحفاظ علي الآثار وميكنة البيانات الخاصة بهذا التراث الحضاري والثقافي، وفيما يلي ملخص لخطة الترميم المقترحة للحفاظ على بعض المواقع الأثرية في موقعي هضبة أهرامات الجيزة والواحات الخارجة:

خطة لترميم وصيانة بعض المواقع الأثرية
في هضبة الجيزة والواحات الخارجة

تجدر الإشارة إلى أن تطبيق عملية الترميم والصيانة يجب أن تستند إلى خطة علمية تعتمد على التوثيق العلمي وعمليات الفحص والتحليل. وعلى هذا الأساس تم وضع خطة الترميم والصيانة لبعض الآثار (الشكل التالي) في موقعي هضبة أهرامات الجيزة والواحات الخارجة كما يلي:



شكل يوضح الخطة المقترحة ترميم وصيانة بعض الآثار في موقعي هضبة أهرامات الجيزة والواحات الخارجية

من القواعد الأساسية في علم الترميم أن أي عملية ترميم يجب أن ترتكز على دراسة مستفيضة للأعمال السابقة والدراسات العلمية المتخصصة. التخطيط، المنهجية وفحص وتحليل لمواد البناء المستخدمة في بناء الموقع الأثري موضوع الدراسة. وتعد تلك الخطوات الأولى من أهم بدايات أعمال الترميم للتحقق ولتحديد حالة الأثر الراهنة ومظاهر وعوامل التلف الفعلية بالموقع ومن ثم اختيار الطرق الفضلى للترميم والصيانة.

هضبة الجيزة (أهرامات الجيزة- تمثال أبو الهول):

تعتبر منطقة هضبة الجيزة وما تحتويه من آثار موغلة في القدم من أهم المناطق الأثرية ليس فقط بمصر ولكن في العالم كله.

وتتكون مجموعة هضبة الجيزة من :

- مجموعة هرم خوفو.
- مجموعة هرم خفرع متضمنة تمثال (أبو الهول).
- مجموعة هرم منكارع.

من واقع الزيارات الميدانية لمنطقة هضبة الجيزة أظهرت الملاحظات الحقلية والاختبارات الأولية لمواد البناء وجود عوامل تلف مختلفة تهدد وتهاجم المنطقة وما زالت تهدد وجود المجموعات الهرمية بهذه المنطقة، ومن أهم تلك العوامل ما يلي:

أولاً : الأهرامات الثلاثة :

- الاختلاف اليومي الهائل بين درجات الحرارة ودرجات الرطوبة.
- عوامل التعرية الجوية.
- الصدوع والفواصل الجيولوجية.
- ارتفاع منسوب الماء الأرضي.
- نحر الرياح.
- التلف البشري.
- التلوث الجوي.

ثانيًا : أبو الهـــــول :

- ضعف وعدم تجانس التكوين الجيولوجي للهضبة المنحوت منها جسم التمثال.
- الاختلاف اليومي الهائل بين درجات الحرارة ودرجات الرطوبة.
- عوامل التعرية الجوية.
- الفواصل والكسور الجيولوجية.
- ارتفاع منسوب الماء الأرضي.
- نحر الرياح.
- الترميم الخطأ.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمنطقة هضبة الأهرامات:

- تجميع وفحص كل الدراسات والأعمال السابقة والخاصة بمنطقة هضبة الأهرامات خاصة الدراسات الخاصة بإعمال الترميم وخواص مواد البناء والدراسات الجيولوجية والهيدرولوجية.
- التوثيق العلمي لنقوش والكتابات الأثرية.
- فحص ودراسة عينات مواد البناء بالمنطقة.
- تخفيض منسوب الماء الأرضي وتقوية المناطق الصخرية الضعيفة خاصة في منطقة منخفض أبو الهول.
- اختيار الأسلوب الأفضل لعلاج الفواصل والصدوع الصخرية بكامل المنطقة وخاصة بالمنحدر الشمالي لهرم خفرع.
- وضع خطة علاج علمية للحد من ظاهرة نحر الرياح خاصة بجسم أبو الهول.
- تنمية وزيادة الوعي الأثري بأهمية الحفاظ على المنطقة الأثرية.

معـــبد هيبس :

أظهرت الملاحظات الحقلية والاختبارات الأولية لمواد البناء بموقع معبد هيبس عوامل تلف مختلفة تهدد وتهاجم المعبد وما زالت تهدد وجود هذا المعبد، ومن أهم تلك العوامل ما يلي:

- عيوب التربة، ارتفاع منسوب الماء الأرضي أسفل أساسات وأرضية المعبد (عامل التلف الرئيسي للمعبد).
- التلف الناتج عن الكائنات الحية الدقيقة.
- نحــر الرياح.
- الإتلاف البشري.
- الترميم الخطأ.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمعبد هيبس:

- التوثيق العلمي للنقوش والكتابات الأثرية.
- فحص ودراسة عينات مواد البناء بالمنطقة.
- صلب الأجزاء الضعيفة من المعبد (جدران- أعتاب- أسقف... الخ).
- تخفيض منسوب الماء الأرضي وتقوية التربة.
- وضع خطة لوقف تأثير الكائنات الحية الدقيقة المتلفة (بكتريا، فطريات).
- تنظيف أسطح المعبد الخارجية.
- استكمال الأجزاء المفقودة.
- تقوية مواد البناء.
- تقوية النقوش وطبقة الألوان.

مقابر البجوات الجماعية :

أظهرت الملاحظات الحقلية لموقع مقابر البجوات الجماعية عوامل تلف مختلفة تهدد وتهاجم مقابر البجوات وما زالت تهدد الكنائس الأثرية بالموقع، ومن أهم تلك العوامل ما يلي:

- الاختلاف اليومي الهائل بين درجات الحرارة ودرجات الرطوبة.
- نحر الرياح.
- الأمطار والسيول.
- التلف البيولوجي (العضوي).
- التلوث الجــوي.
- الإتلاف البشري.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمقابر البجوات الجماعية :

- التوثيق العلمي لكل آثار منطقة البجوات.
- فحص ودراسة عينات مواد البناء بالمنطقة.
- تسجيل وتوثيق الصور الجدارية الموجودة بداخل الكنائس الأثرية.
- تنظيف الصور الجدارية الموجودة بداخل الكنائس الأثرية.
- استخدام الطرق العلمية الحديثة لحماية الصور الجدارية من التلف العضوي.
- تقوية الصور الجدارية بكل طبقاتها.
- عزل أسطح الكنائس الأثرية لحمايتها من الأمطار وعمليات التكثيف.
- إعادة بناء الأجزاء المفقودة خاصة في الأركان.
- استكمال أماكن المونة المفقودة.
- تقوية الطوب اللبن الضعيف.

معبد الناضـــورة :

أظهرت الملاحظات الحقلية والاختبارات الأولية لمواد البناء بموقع معبد الناضورة عوامل تلف مختلفة تهدد وتهاجم المعبد وما زالت تهدد وجود هذا المعبد، ومن أهم تلك العوامل ما يلي:

- الاختلاف اليومي الهائل بين درجات الحرارة ودرجات الرطوبة.
- نحر الرياح.
- الطمر بالكثبان الرملية.
- الإتلاف البشري.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمعبد الناضورة :

- التوثيق العلمي للنقوش والكتابات الأثرية.
- فحص ودراسة عينات مواد البناء بالمنطقة.
- تنظيف الأسطح الحجرية للمعبد.
- تقوية الحجر الجيري.
- وضع خطة لوقف تأثير الكثبان الرملية المتلف.

معبد قصـــر الزيان :

أظهرت الملاحظات الحقلية والاختبارات الأولية لمواد البناء بموقع معبد قصر الزيان عوامل تلف مختلفة تهدد وتهاجم المعبد وما زالت تهدد وجود هذا المعبد، ومن أهم تلك العوامل ما يلي:

- التأثير المتلف للطيور وأعشاش النحل (عامل التلف الرئيسي للمعبد).
- نحر الرياح.
- الطمر بالكثبان الرملية.
- الإتلاف البشري.
- العيوب الجيولوجية للحجر الرملي.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمعبد قصر الزيان:

- التوثيق العلمي للنقوش والكتابات الأثرية.
- فحص ودراسة عينات مواد البناء بالمنطقة.
- وضع خطة لوقف تأثير الطيور والنحل البري المتلف.
- تقوية مواد البناء.

قصر الغويطـــة :

أظهرت الملاحظات الحقلية والاختبارات الأولية لمواد البناء بموقع معبد قصر الغويطة عوامل تلف مختلفة تهدد وتهاجم المعبد وما زالت تهدد وجود هذا المعبد، ومن أهم تلك العوامل ما يلي:

- التلف الناتج عن الكائنات الحية الدقيقة.
- نحر الريـــاح.
- الطمر بالكثبان الرملية.
- الإتلاف البشـــري.

وفيما يلي الخطوط العريضة لخطة العلاج المقترحة لترميم وصيانة الموقع الأثري لمعبد قصر الغويطة:

- التوثيق العلمي للنقوش والكتابات الأثرية.
- وضع خطة لوقف تأثير الكائنات الحية الدقيقة المتلفة (بكتريا، فطريات).
- فحص ودراسة عينات مواد البناء بالمنطقة.
- تنظيف أسطح المعبد الخارجية.
- استكمال الأجزاء المفقودة.
- تقوية مواد البناء.